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AND ABSTRACT OF THE LITERATURE

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A Preliminary Note on Dysmenorrhea as an Industrial Problem

Analysis of 123 Cases of Anthrax in the Pennsylvania Leather Industry

Experiments in Air Conditioning

Experimental Observations upon the Relation between Atmospheric Conditions and the Production of Fatigue in Mine Laborers
(*Continued*)

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THE JOURNAL OF INDUSTRIAL HYGIENE

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A PRELIMINARY NOTE ON DYSMENORRHEA AS AN INDUSTRIAL PROBLEM*

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DYSMENORRHEA is the commonest of all female ailments. With the increasing employment of women in industry, it is timely to consider the industrial aspects of this condition. Two problems at once present themselves. The first is to determine the industrial incidence of dysmenorrhea—the extent to which industry is crippled from this cause. The second problem is to discover how the situation can most efficiently be handled.

INCIDENCE

From the purely clinical point of view, it is sometimes difficult to say just what degree of menstrual discomfort is to be rated as dysmenorrhea. From the industrial point of view, the definition of the term is simple. In this sense dysmenorrhea is any catamenial disability which lessens the efficiency of the employee.

Industrial crippling from dysmenorrhea may occur in three ways: (1) A girl may do her work without complaint, but with a lowered general efficiency. (2) A girl may begin her work, but be compelled in the course of the day to report to the rest room or hospital. (3) A girl may stay at home for a full day, or longer.

Statistics in regard to the first group of cases are not obtainable. Certainly this group in the aggregate does not account for any considerable industrial loss. Possibly in the occasional case of a skilled individual worker or executive the lowered efficiency might be noticeable.

In regard to the second group of girls, those who report to the rest room or hospital, data are easily available. Table 1 contains figures which have been obtained from four large industries—a factory, two department stores, and a telephone exchange. From these figures it appears that, on the average, rather over 10 per cent. of the girls in an industrial establishment may be expected to seek relief for their menstrual dis-

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abilities during any given month. Naturally, there are many factors which may influence this figure. The age, nationality, and general type of the girls, the attitude of the firm and its executives, and the feeling existing among the employees toward the medical department, might all tend to increase or decrease the average figure in the case of any particular industry.

at least three-fifths, and probably nearly four-fifths of the female staff had occasion, sometime during the year, to report because of menstrual troubles. The comparatively small number of "repeaters" recorded in Table 2 may be explained by the fact that the industrial plant from which these figures were obtained is one of the few that makes a practice of interrogating prospective

TABLE 1.—GIRLS REPORTING TO REST ROOM OR HOSPITAL

Industry	Period	Total Number of Girls	Average Number per Month Reporting for Dysmenorrhea	Per Cent. Reporting
A	1919	2,141	152	7.1
	1920	2,385	131	5.6
B	Oct.-Dec., 1920	750	81	10.8
C	Oct.-Dec., 1920	600	80 (estimated)	13.3
D	December, 1914	1,000	153	15.3
	March-Sept., 1919	1,000	122	12.2

In regard to the number of "repeaters" who report month after month, the figures in Table 2 are offered, from which interesting conclusions can be drawn. Out of 1,750 girls, 96 reported three or more times during eleven months, making a total of 441 visits. In this particular organization, 12 per cent. of the total employees reported per month. In eleven months, then, 0.12 x 1,750 x 11, or 2,310 visits were made to the hospital because of dysmenorrhea. But 441 of these visits were made by the 96 "repeaters," and

TABLE 2.—NUMBER OF "REPEATERS" AMONG 1,750 GIRLS DURING ELEVEN MONTHS

2	girls reported	10	times
4	" "	9	"
3	" "	8	"
6	" "	7	"
16	" "	6	"
10	" "	5	"
8	" "	4	"
47	" "	3	"

so 1,869 must have been made by 1,654 other girls, of whom many undoubtedly came once only, and none came more than twice. It follows, therefore, that

employees about their catamenial disability, and of rejecting those who admit being regularly incapacitated.

When we consider the disposal made of the girls who report to the hospital, figures from the different industries are strikingly in agreement. Nearly one-half of all those reporting receive a hot drink, and return to their work after resting ten or fifteen minutes; thus, the amount of lost time is negligible. Somewhat less than one-half lie down for varying periods of time, ranging from fifteen minutes to four hours; the average time actually lost from work in these cases is about two hours. About one-eleventh of the girls reporting are sent home for the rest of the day; the industrial loss in such a case should be reckoned as nearly a full day, since such work as may have been done before reporting is usually no great contribution to the efficiency of the industrial machine.

It is most difficult to obtain figures in regard to the third group of cases, those who stay at home altogether for

a full day or longer. In nearly all industrial plants short absences, for less than three days, are listed as being "for personal reasons," and a more detailed statement of the cause is not required. At the same time, this is the most important group, both from the economic and from the medical point of view. Table 3 is based on periodic absences

TABLE 3.—PERIODIC ABSENCES AMONG 356 GIRLS DURING SIX MONTHS

11	girls	stayed	out	6	times
31	"	"	"	5	"
41	"	"	"	4	"

at intervals of twenty-eight days, which were, therefore, in all probability due to dysmenorrhea.

How many girls stayed out for the same reason three times, twice, or once in the six months it is, of course, not possible to tell from the records. It is a very conservative estimate to assume that fifty stayed out three times, fifty twice, and sixty once, in the half-year. Allowing these figures, which err, if at all, on the side of being too small, then we have a total of 695 days lost among 356 girls during a period of six months. The total days of work during this period were 64,080, so that the industrial loss caused by this group of girls exceeds 1 per cent. of the total time of the employees.

Tabulating the foregoing observations, it becomes very obvious that the third group of cases is the one chiefly responsible for industrial loss from dysmenorrhea (Table 4).

Management

In this connection two opportunities are offered to the industrial physician. The first is the chance to provide proper care for those girls who come voluntarily to the hospital. The second and larger opportunity is along lines of education, particularly among the worst cases, such as those who stay at home.

In most instances where an industry has an organized medical department, the first of these opportunities is fairly well met. The necessary arrangements include a room with cots, sufficiently isolated from observation and disturbance. A tactful nurse is in attendance, and the physician is available for severe cases, or those who wish to see him. Hot-water bottles or electric heating-pads are at hand, and sanitary napkins are provided when needed. There is a supply of malted milk or other ingredients for hot drinks, as well as a selection of suitable drugs. Whether these last may be administered by the nurse, in

TABLE 4.—LOSS PER MONTH OF TWENTY-FIVE WORKING DAYS PER 100 GIRLS

	Days Lost
Group I	
(Loss not reckonable; probably negligible).	....
Group II	
Subgroup A—10% of 100 report; ½— of these lose practically no time.....	....
Subgroup B—10% of 100 report; ½— of these lose 2 hours each.....	1+
Subgroup C—10% of 100 report; 1/11 of these lose 1 day each.....	1—
Group III	
1% of total working days.....	25

accordance with fixed directions, is a question to be settled by each physician.

The possibilities of the second opportunity are large, from both the industrial and the medical points of view. Women are amazingly backward about seeking relief for their menstrual difficulties. The aggregate of unnecessary suffering which is silently borne every month is dreadful to contemplate. Tradition dictates that this is part of woman's lot, and will probably improve after marriage, and the inertia of false modesty adds the final inhibiting touch. The purpose of this paper is not to discuss the treatment of dysmenorrhea; it

is sufficient to say that the greater part of such suffering can be prevented by simple measures, and in most cases without a pelvic examination. The problem is to bring this fact to the knowledge of the girls, and to impress upon them the desirability of having their trouble corrected.

Nowhere else is there such an opportunity as in industrial medicine to spread propaganda of this sort. And yet the physician must proceed with considerable tact and caution, for resentment would certainly be aroused by the idea that such investigations were being forced upon female employees. There are two occasions when the subject could be properly introduced—at the time of hiring, and again when a girl reports to the hospital for dysmenorrhea. If our figures are correct, nearly four-fifths of the female staff would be reached in the latter way during the course of a year. Good news spreads fast, and a few cured patients are excellent advertising.

The attitude of employers seems to be, for the most part, one of indifference. Either they do not appreciate the extent of the problem, or they consider it impossible of solution through the machinery of industrial medicine. If they are enlightened on both of these points their co-operation in any scheme of improvement should be assured.

The first need is to train the physician in the industrial aspects of dysmenorrhea, as well as in the diagnosis of the different clinical types and in the ordinary therapeutic measures. Without such fundamental knowledge there can be no successful handling of the problem.

I wish to thank the different industrial physicians who have so kindly helped me in obtaining statistics and other information on this subject.

ANALYSIS OF 123 CASES

OF

ANTHRAX IN THE PENNSYLVANIA LEATHER INDUSTRY*

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IN connection with a recently completed survey of the anthrax hazard in the tanning industry in Pennsylvania, accounts of which are to be published elsewhere (1) (2), we have tabulated 123 cases of human anthrax traceable to the materials handled. It is the purpose of this paper to make an analysis of the data obtained in connection with these cases.

For the purposes of this study the tanneries in which these anthrax cases originated may be divided into two classes: those handling cattle hides, and those handling goat skins. Cattle hides are received green salted, dry salted or earth dried. The green salted hides are tied individually in square bundles with the hair side in, and the dried hides are in bales. Green salted hides give rise to practically no dust, and therefore are safer to handle in the raw state. Most of the cattle hide tanneries are packer controlled and at present are tanning almost exclusively hides from packer killed cattle, either domestic or South American. These beef cattle are almost sure to be free from anthrax. There are, however, some non-packer hides imported at present and many of these are dry. Anthrax has been caused by handling these dry hides and also by handling green salted non-packer hides. When business conditions return to normal, many more of these non-packer hides will be tanned, as was formerly the case. In 1921 there were four tanneries using dry hides, and in 1918 there were twelve. Before that time many tanneries handled no other stock.

Raw stock is soaked in water and then in strong lime suspensions, after which it is dehaired and washed, and is ready for tanning. The strong lime soaks rapidly reduce the numbers of anthrax spores on the hides, and the hides are practically free from danger by the time they are dehaired and washed. The occasional anthrax cases occurring in the later departments of the tannery are probably accidental dust or contact infections from these first processes. On this assumption we have figured that in the fifty-seven cattle hide tanneries included in our study, having an estimated working force of 7,458 men, there were 614, or slightly over 8 per cent. of the men, directly exposed to anthrax risk. In the nineteen goat skin tan-

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neries employing 5,881 men, 426, or somewhat over 7 per cent., were directly exposed. This gives a total of 1,040 directly exposed men in the industry, or not quite 8 per cent. of the employees (see Table 1). Of these men at least

TABLE 1.—TANNERS EXPOSED TO ANTHRAX

Tanneries	Total Employees	Exposed to Anthrax	
		Number	Per Cent.
57 cattle hide tanneries	7,458	614	8+
19 goat skin tanneries	5,881	426	7+
Total	13,339	1,040	7.8

119 contracted anthrax in the twelve years included in our study, and four more cases developed in those handling raw hides or skins, making 123 cases in all, or over 11 per cent. of the number of directly exposed tanners. Seventy-three of these cases were due to the handling of cattle hides (Fig. 1), and fifty to the handling of goat skins.

No cases of anthrax have as yet been traceable to the handling of domestic hides, with the exception of one case in 1918 from Texas hides. Table 2 indicates the source and condition of hides being handled in the twenty-eight cases among cattle hide tanners and the four cases among goat skin tanners in which we have definite information on the subject. This table shows anthrax traceable to hides from Texas, India, China, Mexico, South America and Cuba, in twelve or more cases from dry hides, but in two of them from green salted hides. In many cases among cattle hide tanners and in most cases among goat skin tanners we could obtain no records as to the source or condition of skins handled at the time.

Hides and skins being imported into this country are supposed to come in under quarantine unless accompanied by a consular certificate stating that they are from a district free from anthrax. Our experience agrees with that of others to the effect that this certification is worse than useless since it merely establishes a false sense of security among the tanners and freight handlers. Reference to Table 2 will show that four of the reported cases are known to have been contracted from handling certified hides. Indeed, one of us has cultured anthrax a number of times from samples from certified materials (2).

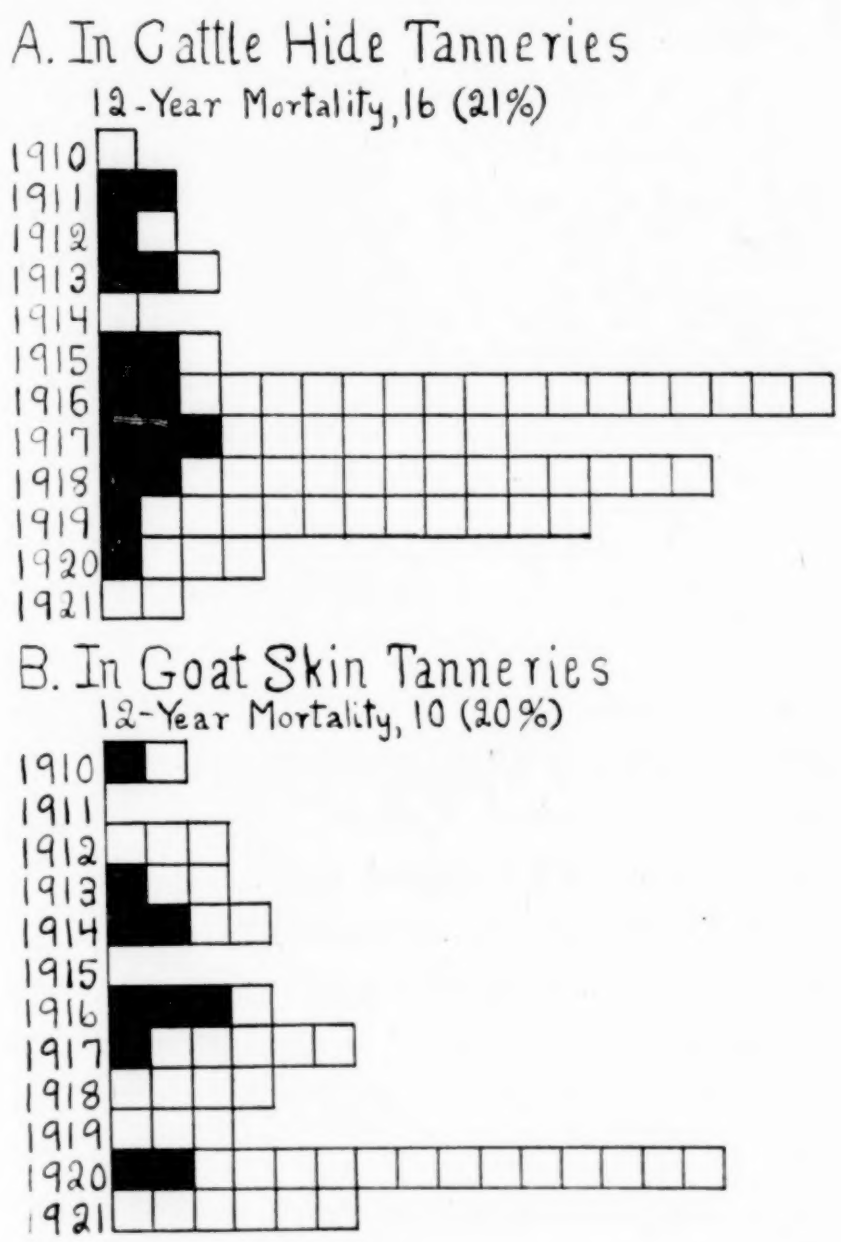

Fig. 1.—Yearly morbidity and mortality from anthrax in Pennsylvania tanneries. Total mortality, 26 (21%). Squares represent cases; black squares, fatalities.

Table 3 shows the distribution of anthrax cases among tanneries. For convenience in differentiation cattle hide tanneries are listed by number, and goat skin tanneries by letter. This table shows anthrax cases in twenty-three of the fifty-seven cattle hide tanneries, or over 40 per cent., there being thirteen with one case each, one with two cases, one with three cases, three with four cases, two with five, one with six, one with nine, and one with fifteen cases in twelve years. The last tannery had two years with five cases, and tannery number 18 had one year with five cases. In this twelve-year period there were sixteen deaths from anthrax in cattle hide tanneries, one tannery losing two cases in one year; fourteen of these sixteen deaths were from eleven tanneries, the other two being in a hide contractor and a freight agent, respectively. In goat skin tanneries cases have been reported from eight out of the nineteen tanneries of this type of which we have any records. In addition, there were seven cases reported among tannery workers but no statement was made as to where they were employed, and two cases were reported in longshoremen handling skins. In this group of tanneries three had one case each, one had two cases, one three, one six, one eleven, and one sixteen cases in the twelve years, with six cases in 1920, and five in 1921.

These records are, we feel, fairly complete from 1916 on. Before that date we feel sure that we must have overlooked a number of cases. Records were obtained from the following sources: Bureau of Labor Statistics, Bulletin No. 267; Pennsylvania State Health Department records; hospital records; and reports from physicians and from tannery superintendents. Health department records are very meager, and many cases are not reported at all. Tannery records, except for recent years, are, we find, very vague both as to date and diagnosis. The best records available were those of hospitals and tannery physicians. The source from which the greatest number of case records was obtained was a physician in central Pennsylvania who treated cases for several of the largest sole leather tannery corporations. His records gave us a number of cases not listed elsewhere, but as furnished us they did not go back beyond 1916. His cases were all treated in his own hospital and the diagnosis was confirmed in the laboratory as were the diagnoses of cases treated in the other hospitals.

Figure 1 shows the cases and deaths listed by years. Here is noticed the great apparent increase in cases in 1916 due to the obtaining of more complete records. The decrease in 1920 and 1921 in cases from cattle hide tanneries is due

TABLE 2.—SOURCE AND CONDITION OF HIDES AND SKINS HANDLED BY WORKERS INFECTED WITH ANTHRAX

Raw Material	No. of Cases	Country of Origin	Dry or Wet	Certified
Cattle hides	1	Texas	—	—
" "	2	India	dry	—
" "	9	India and China	dry	—
" "	1	China and South America	dry	—
" "	12	South America	2 green salted	3 certified
" "	1	South America and Mexico	dry	certified
" "	1	Mexico	dry	—
" "	1	Cuba	dry	—
Goat skins	4	India	wet salt	—

TABLE 3.—ANTHRAX CASES IN TANNERIES[1]

A. Cattle Hide Tanneries

Tannery No.	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	Tannery No.
1	1 (1)								1				1
2		1 (1)											2
3		1 (1)					5	3		5 (1)	1		3
4			1 (1)										4
5			1				2				2		5
6				1									6
7				1 (1)				1 (1)		2			7
8					1								8
9						3 (2)	1						9
10							2		2	1			10
11							1		3				11
12							1 (1)						12
13							3 (1)	1	2				13
14							1						14
15							1	1			1 (1)		15
16								1 (1)					16
17								1					17
18								1	5 (1)	1		2	18
19								1 (1)					19
20									1				20
21									1				21
22										1			22
23										1			23
Not traceable to any tannery				1 (1)[2]			1 (1)[3]			1			Not traceable to any tannery

73 cases in 23 tanneries; 16 deaths in 11 tanneries.

B. Goat Skin Tanneries

A	1										4 (1)	1	A
B			1		1								B
C				1 (1)									C
D				1						1	1		D
E							1	2	1	1	6 (1)	5	E
F							1 (1)						F
G								4 (1)	2	1	4		G
H									1				H
Not traceable to any tannery	1		2 (1)[4]	1	3 (2)[5]		2 (2)						Not traceable to any tannery

50 cases in 8 tanneries; 10 deaths in 5 tanneries.

[1]Numbers in parentheses represent fatalities.
[2]Freight agent.
[3]Contractor.
[4]Longshoreman.
[5]One longshoreman.

to business depression and decrease in importation of non-packer hides liable to contain anthrax. As stated above, we feel that this condition is only temporary.

Table 4 shows the effect of hospitalization resulting from early diagnosis on mortality rates and on time lost in non-fatal cases. This table includes cases from both groups of tanneries. It shows that of the ninety-seven cases which were hospitalized only ten, or about 10 per cent., died, while of the twenty-six cases which were not hospitalized sixteen, or over 61 per cent., died. As a complement to this there is also shown the number of cases in which we have a record of laboratory diagnosis. Only two cases that were so diagnosed were not sent to a hospital, possibly because the diagnosis was made too late, as both patients died. The neglect to make a laboratory confirmation of a diagnosis of anthrax in a tannery employee is inexcusable. The diagnosis by smear, culture or animal inoculation is simple and unmistakable, yet we have a record of a fatal case not included in this list, that of a patient dying in a large hospital in the state, whose death was reported on the certificate as due to anthrax merely because he was a tannery worker. A search of the records showed a laboratory diagnosis, by blood culture and smear, of staphylococcus septicemia. This developed from an infected wound made by running into the hand a splinter from a new loft stick used for tanned hides. This occurred in a tannery handling nothing but packer hides and in an employee handling only tanned hides. Such errors would be fewer if a little more care were exercised in history taking.

Not only is a hospitalized case more apt to get good nursing and the required absolute rest and supportive treatment, but it is also more apt to receive intelligent specific treatment of some kind. As such a large proportion of these cases were so hospitalized and as each hospital as a rule used one specific method of treatment, we have a good opportunity to throw some light on the relative merits of treatment methods. In the state of Pennsylvania the cases of which we have treatment records group themselves into three divisions: Some received serum injections; some, injections of 25 or 50 per cent. phenol in the next vascular area to the carbuncle; and in some cases the lesions were excised. These methods of treatment were used alone or in varying combinations which have been recorded in Table 5.

Regan, in a recent article (3), makes

TABLE 4.—RESULTS OF HOSPITALIZATION FOR ANTHRAX

Hospital No.	Total Case	Deaths		Recoveries		Record of Time Lost in Non-Fatal Cases	
		No.	Per Cent.	No.	Per Cent.	No. of Cases	Average No. of Days
1	39	4	10.25	35	89.75	31	43.8
2	7	0	0.0	7	100.0	7	31.8
3	1	0	0.0	1	100.0	1	60.0
4	46	4	8.7	42	91.3	36	32.1
5	2	2	100.0	0	0.0	.....	.....
6	2	0	0.0	2	100.0	2	39.0
Total hospitalized	97	10	10.3	87	89.7	77	37.3
Total non-hospitalized	26	16	61.5	10	38.5	5	55.4
Laboratory diagnosis recorded	99	12	12+	.....	.....	.....	.....
No record of laboratory diagnosis	24	14	58+	.....	.....	.....	.....

a strong plea for the exclusive use of serum locally and generally, claiming the best results from this method. He reports eight successful cases so treated, without a death, and quotes a long series of reports from different parts of the world showing a total mortality of 6.7 per cent. in 446 cases, exclusive of his own. Our Pennsylvania statistics show a general mortality of over 21 per cent. but the hospitalized cases show a mortality of a little over 10 per cent. One hospital, where the routine treatment consists of 25 per cent. phenol injections and wet bichloride of mercury dressings, has treated seven cases without a death, a record practically as good as Regan's. In eighty-six of the Pennsylvania cases the local lesion was excised, ten of the patients dying—a mortality of 11.6 per cent. Of the eighty-six cases, thirty-seven which were treated in a large city hospital received serum injections also, but in five instances the disease was fatal—a mortality of 13.5 per cent. Forty-seven of the patients treated by excision also received 50 per cent. phenol injections around the wound, and five of these died—a mortality of 10.6 per cent. Of the thirteen patients not having the lesion excised, four died, or 30.7 per cent. Two patients treated by excision alone both recovered.

Of a total of forty-three cases receiving serum treatment, nine were fatal, giving a mortality of 20.9 per cent., which is much higher than the average mortality quoted by Regan. Of fifty-six patients not receiving serum, five died, or 8.9 per cent., a mortality less than half that for the cases receiving serum. The high mortality of the serum treated cases is due to one fatal case receiving serum and phenol injections and three fatalities among the five cases receiving serum alone. Of the thirty-seven patients receiving serum and also having the local lesion excised, only five died, giving a mortality of 13.5 per cent. Thirty-four of these cases, four of them fatal, were treated in one large city hospital, giving a mortality of under 12 per cent., a very fair record for this number of cases. Next to the seven successful cases treated in one hospital by phenol injections and local antiseptic dressing, the best record obtained was in the forty-seven cases treated by excision and phenol injections, with a mortality of 10.6 per cent. Forty-six

TABLE 5.—RESULTS OF SPECIFIC TREATMENT METHODS

Treatment	No. of Cases	Deaths		Recoveries		Record of Time Lost by Non-Fatal Cases	
		No.	Per Cent.	No.	Per Cent.	No. of Cases	Average No. of Days
Serum alone	5	3	60	2	40	1	31.0
Serum and phenol injections	1	1	100.0	0	0	—	—
Serum and excision	37	5	13.5	32	86.5	28	45.2
Total serum	43	9	20.9	34	79.1	29	44.7
Total without serum	56	5	8.9+	51	91+	44	32.4
Excision alone	2	0	0	2	100.0	1	47.0
Excision and serum	37	5	13.5	32	86.5	28	45.2
Excision and phenol injections	47	5	10.6	42	89.4	36	32.1
Total excisions	86	10	11.6	76	88.4	65	36.9
Total without excision	13	4	30.7+	9	69.2+	8	31.7
Phenol injections alone	7	0	0	7	100.0	7	31.8
Phenol and serum	1	1	100.0	0	0	—	—
Phenol and excision	47	5	10.6	42	89.4	36	32.1
Total phenol	55	6	10.9	49	89.1	43	32+
Total without phenol	44	8	18.1+	36	81.8+	30	44.8
No record of specific treatment	24	12	50.0	12	50.0	9	52.2

of these cases were treated by one man, with only four fatalities, a mortality of under 9 per cent., and an excellent record, especially as a number of these cases occurred in small towns, some over a hundred miles from the physician's office, to which they were transported by train or by automobile. This record would not be possible if it were not that the tanners have been on a constant lookout for anthrax infection and that they send cases for diagnosis on the earliest development of a suspicious lesion. The very great value of early diagnosis is seen by comparing these figures with New York City anthrax mortality statistics for 1915 to 1919, quoted by Regan (3), which show a mortality for the five-year period ranging from 26 per cent. in 1918 to 75 per cent. in 1916. These New York cases were mostly shaving brush infections having no connection with the patient's occupation and therefore usually not diagnosed as anthrax until a generalized bacteremic condition had developed. The great improvement shown by the 1920 mortality rate of 8.5 per cent. is undoubtedly largely due to the prompt, liberal use of serum, as Regan claims, but it is contributed to largely by the earlier diagnosis due to the publicity given to the likelihood of this mode of infection.

In addition to the mortality figures given above for the Pennsylvania cases, Tables 4 and 5 show records of time lost by eighty-two non-fatal cases, seventy-seven of which were treated in hospital, with an average of 37 days' lost time, and five were not hospitalized, with an average of over 55 days' lost time. Treatment in hospital evidently shortens materially the duration of illness and incapacity, as well as enhancing the probability of recovery. In no non-hospitalized case was the patient away from his work for less than 31 days, while the shortest time lost among the hospitalized cases was 7 days. In twenty-three cases, or practically 30 per cent. of the hospitalized cases for which we have time-lost data, there was a loss of 25 days or less per case. Consideration of time-lost data in cases treated by those methods for which we have records of seven or more cases show twenty-eight non-fatal cases treated by excision and serum injection, with an average loss of 45.2 days; thirty-six non-fatal cases treated by excision and phenol injections, with an average loss of 32.1 days; and seven non-fatal cases treated by phenol injection and bichloride dressing, with an average loss of 31.8 days. The shortest disablement period in the first group was 14 days, four of the men (14 per cent.) losing 25 days or less. In the second group the shortest period was 7 days, with sixteen men (44 per cent.) losing 25 days or under. In the third group of seven cases the shortest time lost was 13 days, and the next, 25 days (30 per cent.). As against the average loss of 44.7 days for twenty-nine patients receiving serum injections, we have an average loss of only 32.4 days for the forty-four patients not receiving serum. Against an average loss of 36.9 days for sixty-five patients having the local lesion excised, we have an average of only 31.7 days for the eight cases with no excision, but this group is too small to base much evidence upon, as is the group of seven included in it, which received only phenol injections. Against the average loss of 32+ days for the total of forty-three patients receiving phenol injections, we have an average loss of almost 45 days for the patients not receiving phenol.

The above figures are not offered as an argument against the use of serum,

but rather as an argument for the value, in good hands, of local treatment by excision and by the use of phenol subcutaneously, at least where serum is not available. In the hands of one private physician and of one city hospital, in no way connected with him and in a different part of the state, phenol injections without serum seem to have given excellent results, both from the standpoint of time lost and from that of cure—results practically as good as the most favorable results reported by others from the use of serum intensively. We would state also that the resultant scarring in the cases treated by phenol injections, which we were able to examine, was remarkably inconspicuous, considering the extent of the lesion as evidenced by photographs.

As further evidence of the seriousness of the anthrax risk for exposed tanners, we ask consideration of Tables 6 and 7.

TABLE 6.—TIME LOST BY NON-FATAL CASES OF ANTHRAX

	DAYS
Total non-fatal cases in 12 years	98.0
Average time lost (reports of 82 cases)	38.36
Total estimated time lost	3,759.28
Average estimated time lost per year	313.27
Greatest estimated loss in any tannery (16 cases	613.76
Greatest estimated loss in any tannery in any one year (6 cases)	230.16

Table 6 considers the question of time lost in non-fatal cases. We have records of an average of 38.36 days lost in eighty-two non-fatal cases. This would give an estimated time loss of 3,759.28 days in twelve years in the ninety-eight non-fatal cases, of which we have records, or an average yearly loss for the industry of 313 days. One tannery with a total of sixteen cases would have lost, on this basis, 613.76 days, and with six cases in one year, over 230 days in a single year.

Table 7 gives the morbidity rate among the directly exposed employees for the five years, 1916 to 1920, inclusive, during which period we feel that we have fairly complete and representative statistics. This table shows an average of almost 2 per cent. per year of exposed employees contracting anthrax. The risk is apparently somewhat greater in cattle hide tanneries than in tanneries handling goat skins, in spite of the evident greater prevalence of anthrax infested skins among the raw stock of the goat skin tanneries. There seems to be an idea prevalent among many of the cattle hide tanners that the risk is much greater in the handling of goat skins than in the handling of cattle hides. This is true under the present conditions of the industry, as evidenced by the figures for 1920 and 1921, but, as argued before, this is probably only a temporary condition due to the lack of demand for sole leather. The slightly lower mortality rate among goat skin tanners, as shown in Figure 1, is probably due to early diagnosis and prompt hospitalization, since these tanneries are all in or near Philadelphia and have immediate access to first-class hospitals, and several of the largest of them employ their own physicians. The great increase in the incidence of infection in goat skin tanneries in 1920 is interesting, and has been explained by the tanners in two ways. Owing to the increased demand for leather during the war and the great increase in prices paid for raw materials, many more skins were collected and many inferior skins were baled, which ordinarily would have been refused. The great delays in shipping of all freight overseas caused many of these inferior skins, often infested with anthrax, to be held for a year or more in transit or on open docks ex-

posed to the weather. This resulted in water damage and increase in anthrax in already infested bales. Many of these skins reached the tanneries in 1920.

Cultures made from dust and soak water samples as part of the survey yielded virulent anthrax from 6 per cent. of the cattle hide tanneries and over one-half of the goat skin tanneries where samples were taken, and in many cases these cultures represented so-called certified, supposedly anthrax-free stock (2).

In the discussion of treatment no special mention of internal anthrax was made, as there has been only one case among the 123 cases of anthrax which have occurred in Pennsylvania in the past twelve years, and that case occurred in 1915 in a tannery handling dry cattle hides at the same time, and was, of course, fatal. We have no record as to treatment.

Table 8 gives the occupations of the 123 victims of anthrax. Those listed as laborers are almost all, if not all, workers handling raw or wet-untanned stock. This table shows 111 of the cases among those referred to previously as directly exposed to anthrax risk, only three of the cases being surely in a later department of the tannery. It will be noted that seven men in all have been infected while doing repair work around soak vats. The two cases in housewives are interesting as showing how it is possible for a tanner to take his hazard home with him in his work clothes. Both of these women were tanners' wives, one infecting herself by a needle prick while mending her husband's overalls, and the other presumably becoming infected while doing her husband's wash. These

TABLE 7.—ANTHRAX MORBIDITY IN TANNING INDUSTRY IN PENNSYLVANIA, 1916-1920

Year	Cattle Hide Tanneries		Goat Skin Tanneries	
	No. of Cases	Per Cent. of Exposed Employees[1]	No. of Cases	Per Cent. of Exposed Employees[1]
1916	18	2.9+	4	0.9+
1917	10	1.6+	6	1.4+
1918	15	2.4+	4	0.9+
1919	12	1.9+	3	0.7+
1920	4	0.6	15	3.5+
Five-year total[2]	59	9.6+	32	7.5+
Yearly average[3]	11.8	1.9+	6.4	1.5+

[1]See Table 1.
[2]Five-year total for both types of tannery=91 cases, or 8.7+% of exposed employees.
[3]Yearly average for both types of tannery=18.2 cases, or 1.7+% of exposed employees.

TABLE 8.—KIND OF WORK DONE BY INFECTED EMPLOYEES

Occupation	Total No. of Cases, 1910-1921	Cattle Hide Tanneries	Goat Skin Tanneries
Handling dry skins	25	12	13
Handling wet skins	22	3	19
Laborers	64	53	11
Finishing	2	1	1
Repairing or tearing down	7	4	3
Hair house	1	0	1
Housewives	2	0	2
Total	123	73	50
Cases among persons directly exposed	111 — 10.6% of exposed employees	68 — 93.1% of cases of anthrax	43 — 86% of cases of anthrax

cases offer a strong argument in favor of requiring the disinfection, on the tannery premises, of all work clothing.

Summary and Conclusions

This report lists 123 cases of anthrax connected with the tanning industry in the twelve years from 1910 to 1921, inclusive. This number represents almost 12 per cent. of the directly exposed employees. The mortality among these 123 cases was over 21 per cent.

In the five-year period for which we have accurate statistics, there was a yearly morbidity rate of almost 2 per cent. of the directly exposed employees. The directly exposed employees include those handling raw stock and those soaking and liming this stock.

Anthrax has been contracted from the handling of non-packer cattle hides from Texas, Mexico, China, India and South America, and from goat skins from many regions.

Anthrax has been contracted from the handling of both dry and wet salted hides and skins, and from both certified and uncertified stock, and anthrax bacilli have been isolated from both. The present practice of certification offers little or no protection to the tanner.

The mortality of cases treated in hospitals has been considerably less than one-half that of unhospitalized cases.

In Pennsylvania apparently the best results of treatment have been obtained by the injection of strong phenol solutions (25 to 50 per cent.) locally around the area of the initial lesion, with or without excision of the lesion.

The use of antianthrax serum with excision of the local lesion has also given excellent results, and we do not desire to create the impression that it should not be used. We would be inclined, from a consideration of the Pennsylvania experience, to advocate the continued intensive use of a reliable serum subcutaneously or intravenously, combined with excision of the local lesion and the injection of concentrated phenol solution around the wound. Early diagnosis, prompt hospitalization if possible, and absolute rest are essential for success in any form of treatment.

Anthrax continues to be a decided menace to both the cattle hide and goat skin tanner and will continue to be so until some method is developed whereby tanneries cease to receive anthrax infested raw stock.

Seymour-Jones (4) advocates for England the prohibition of the importation of any raw stock not previously converted to the wet salt state by means of his formic acid and mercuric chloride method. One of us discusses more fully the subject of disinfection for anthrax in another paper (2), but whatever method may be finally adopted, we feel very strongly that all undisinfected imported stock should be disinfected at one or more centrally located government disinfecting stations before being shipped to the tanners, as the English government is doing at present with wool and hair.

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EXPERIMENTS IN AIR CONDITIONING*

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AS a class exercise in the course in ventilation in the School of Public Health of the Harvard Medical School, it was desired to study by direct experimentation certain phases of air conditioning. The White machine of the National Air Treating Company was admirably adapted for our purposes an l was kindly loaned by the company for experiments.

The machine consists of a metal tank 2 feet by 2 feet by 14 inches, above which is mounted a 1/6 horse power Holtzer-Cabot direct current shunt motor driving through bevel gears, a special centrifugal pump and a shaft perforated with holes for throwing the water from the pump out in a fine spray into the spray chamber. In the machine used for demonstration, the spray chamber walls are made of glass. The air enters this chamber through a series of closely spaced, herring-bone baffles, through which the water is returned to the tank. The exit air is freed from entrained water by passing through a like series of baffles to the 1,500 cubic feet per minute exhausting fan which is driven by a direct-connected 1/12 horse power Holtzer-Cabot direct current shunt motor. Both motors run at 1,760 revolutions per minute, 115 volts, while the pump motor is rated at 1.2 amperes and the fan motor at 1 ampere. The motors are connected in parallel and are designed for constant speed, so that starting the machine consists in merely plugging into a standard socket.

The only instrument on the machine for temperature measurement is a thermometer on the pump line to show the temperature of the water entering the spray chamber. This is really all that is needed.

All tests were run in the same room, selected without any particular regard to general thermal conditions, position of ventilators, radiators or windows. The radiator was shut off for all runs, and heat was supplied on Test 4 only from a gas furnace across the top of which air was blown by an electrically driven fan. This fan was kept in place and run at the same speed for all tests. The fan and air conditioning machine were so placed as to cause the minimum of air currents, and both were run at full speed at all times. All instruments were read from the same position relative to the fan furnace and air conditioning machine. The ventilators were blocked off and no external source of ventilation was used. The doors were kept locked. Four men were present in Tests 1 and 4, and five men for Tests 2 and 3.

The outdoor temperature was well below freezing both days these tests were run, and a large window, 6 feet by 8 feet, gave abundant space for condensation during the "humidifying" tests. No attempt was made to obviate this.

For the last three tests, an ejector was used for both emptying and filling the tank of the White machine, so that not more than five to ten minutes elapsed between stopping one run and starting

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the next. In all cases the water level of the tank was kept at as nearly 11 inches as possible. This was equivalent to 4.56 cubic feet, or 20.39 pounds of water per inch.

No tests were made with the tank water at a relatively high and constant temperature, nor were any tests made with a dehumidifying agent at temperatures below 32° Fahrenheit.

Instruments Used

Relative Humidity. — Relative humidity was determined with a "Tycos" sling psychrometer of the U. S. Weather Bureau type, and checked with a portable motor-fan psychrometer and a hair psychrometer, designated a "sling," "motor" and "hair," respectively. The sensitivity of the last instrument was surprising, in view of the wide range of conditions prevailing.

The relative humidity of the moist air delivered from the White machine is not shown on the curves, although wet and dry bulb readings are given in the tabulated results. Regardless of conditions in the room, this exit air is saturated to such a high degree that its determination by wet and dry bulb is difficult and unreliable. It was found impossible to keep the dry bulb dry for more than a few seconds at a time, although water lost by entrainment appeared to be low. The manufacturers claim a relative humidity of over 90 per cent. for this exit air, which appears to be a conservative estimate, while a variation of a few per cent. either way would have little effect on the rapidity with which the desired atmospheric conditions can be obtained.

Air Temperatures. — For both the exit air from the machine and the room air the dry bulb readings are shown on the curves. For the room air the dry bulb readings of the sling and motor-fan psychrometer are averaged.

Water Temperatures. — Readings were taken with a long-stemmed thermometer, the water being thoroughly stirred before each reading. It was found that these readings for run 1 checked those of the thermometer (provided by the manufacturers) in the water intake of the machine so closely that reading of the latter was dispensed with, since the machine was so placed for our tests as to make this reading inconvenient.

Cooling Power of the Air.—Hill's wet and dry kata-thermometer offers a method of determining the cooling power of the air with reference to body temperature, and is described in detail in his monograph on "The Science of Ventilation and Open Air Treatment." This instrument, in brief, consists in an alcohol thermometer with a relatively large bulb of definite surface area and stem of about 1 mm. bore, on which 95° and 100° F. are marked. The bulb is held in hot water until the alcohol, colored red for visibility, has partly filled a small reservoir at the top of the stem, and thus formed an unbroken column. The bulb is then withdrawn and, in the case of the wet kata, excess water removed by pinching the bag at the top. The dry bulb is wiped dry with a clean cloth. The time for the alcohol to fall from the 100° to the 95° mark is then taken in seconds, and the "kata factors," marked on the stems of the instruments, are divided by this time, giving the cooling power of the air, with reference to body temperature, in millicalories per square centimeter per second.

As this instrument is quite sensitive to temperature variations, care must be taken to keep it well away from the body and, for tests such as these, in a definite

location with respect to drafts, to which it is very sensitive. It is advisable to use the mean of several readings, and where this is not possible, as in our tests, at least two sets of instruments should be read simultaneously.

Although at first glance the figures and curves of our kata readings appear to cover a rather wide range without special relation to each other, it will be seen that they show maximal and minimal points at about the same times, which, in turn, bear a definite relation to the humidity readings.

For locations in which the comfort or hygienic aspects of humidity and temperature are the important consideration, the kata-thermometer is useful in connection with wet and dry bulb readings, while for problems of air drying at atmospheric or even reduced pressures the kata-thermometer affords information obtainable with the wet and dry bulb psychrometer only by considering the total heat in the air.

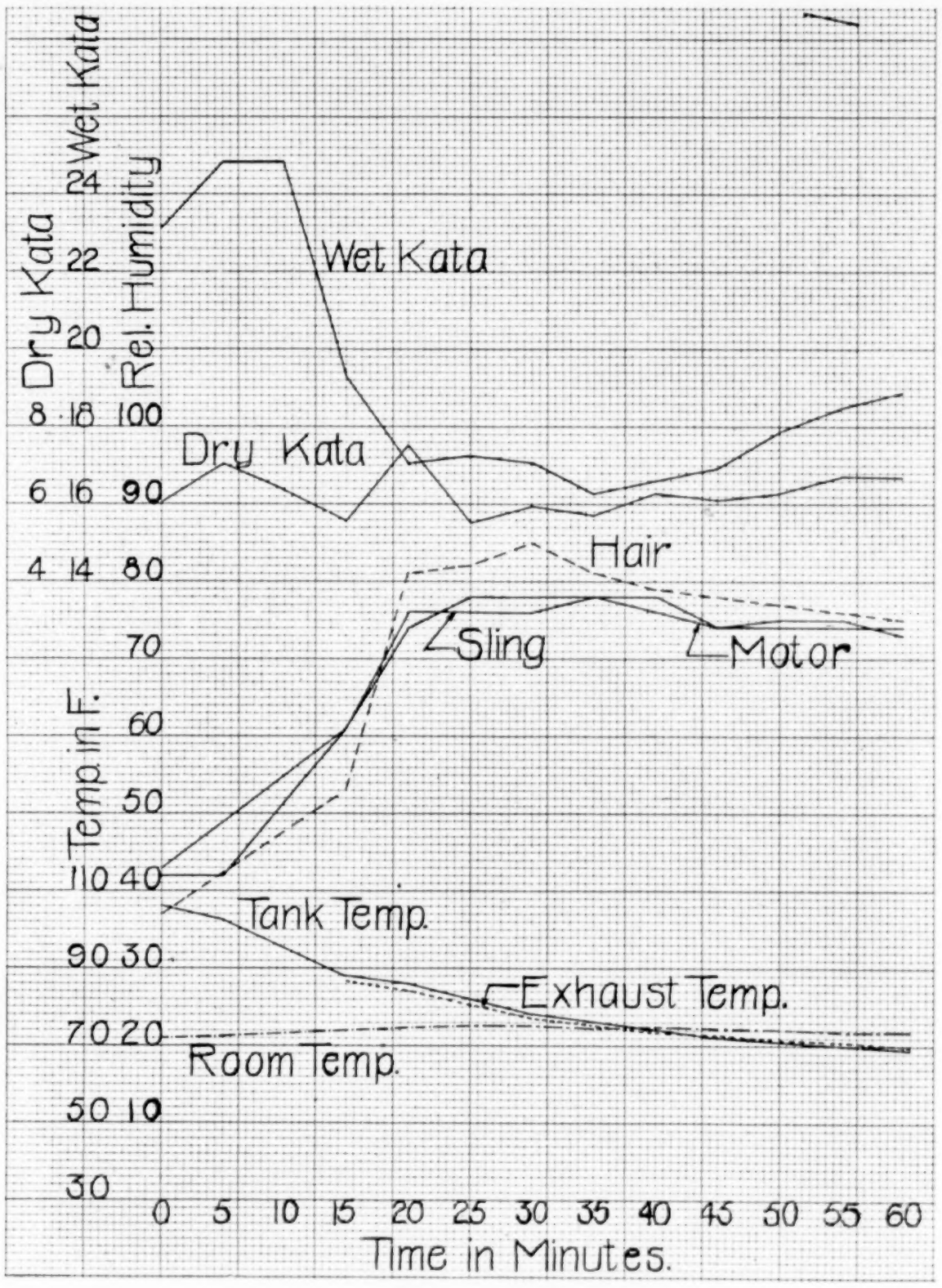

FIG. 1.—Test 1, humidifying. Tank water at initial temperature of 106° F. No attempt to humidify quickly.

TEST 1.—In the first test it was desired to find how quickly and to what extent the room could be humidified when using water at an initial temperature of only 106° F. When the

motors were started the relative humidity was 55 per cent., and was raised to 77 per cent. in ten minutes. The preliminary rise in humidity during the first twelve minutes was due to evaporation from the tank water, as a small hose was used in this run. It will be seen from the curves and data of this test that there is a gradual falling off in humidity after the maximum point is reached, and that this drop in humidity accompanies the drop in temperature of the tank water. The kata-thermometers both show a rise in cooling power as the humidity decreases.

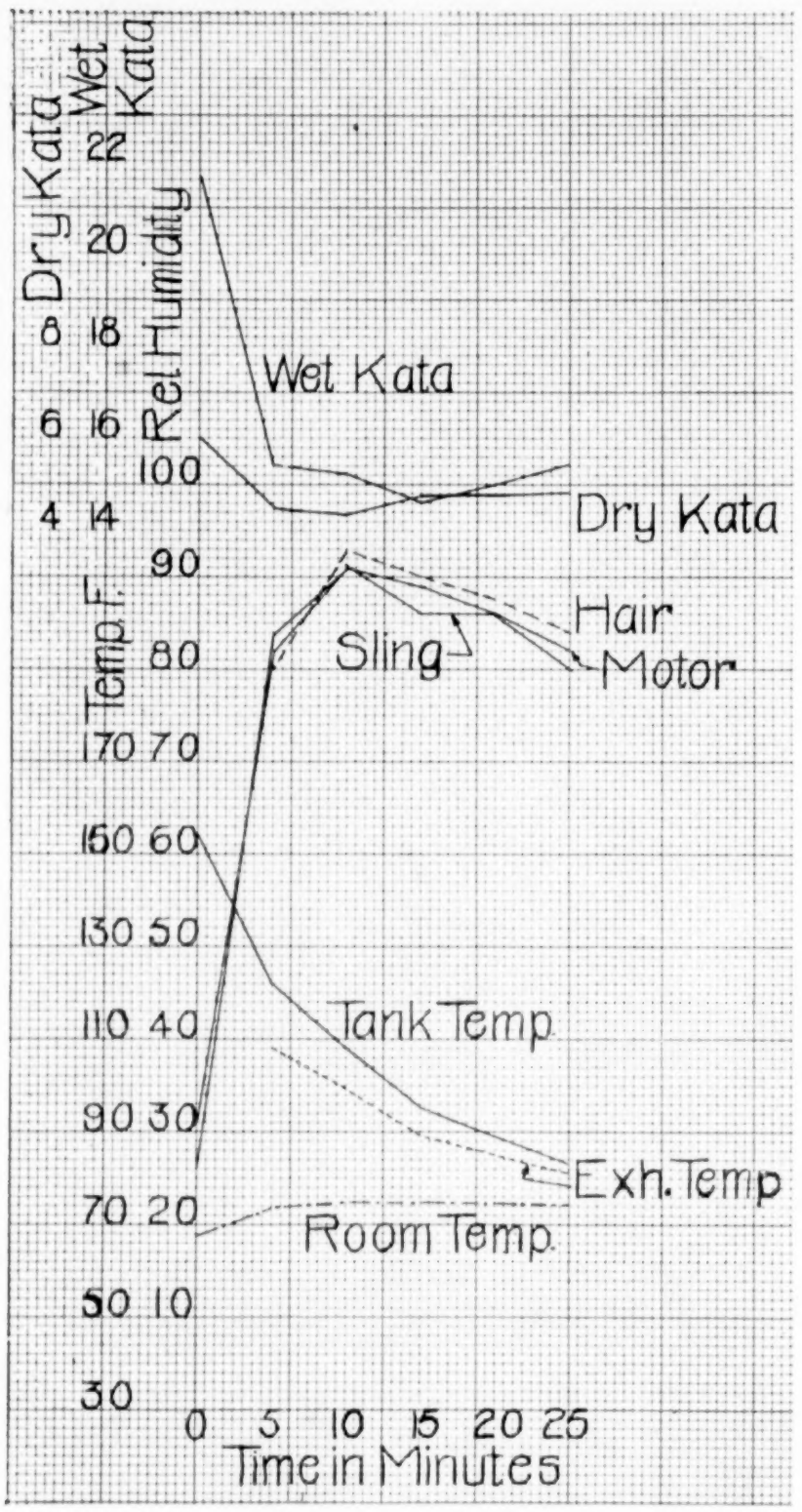

FIG. 2.—Test 2, humidifying. Tank water at initial temperature of 154° F. Humidifying quickly and allowing tank temperature to fall until approximate equilibrium was reached.

TEST 2.—The rapidity with which a high degree of humidity can be reached is well shown in this test. With an initial humidity of 26½ per cent., a maximum of 91 per cent. was reached in ten minutes, with a rise in room temperature of only 9°. This figure could have been maintained by keeping the temperature of the tank water high enough to reach a predetermined equilibrium. A consideration of the curves of this test show that the speed of humidification is greater than in Test 1 owing to the higher initial temperature of the tank water. This is most clearly shown by superimposing the curves of Test 2 on those of Test 1.

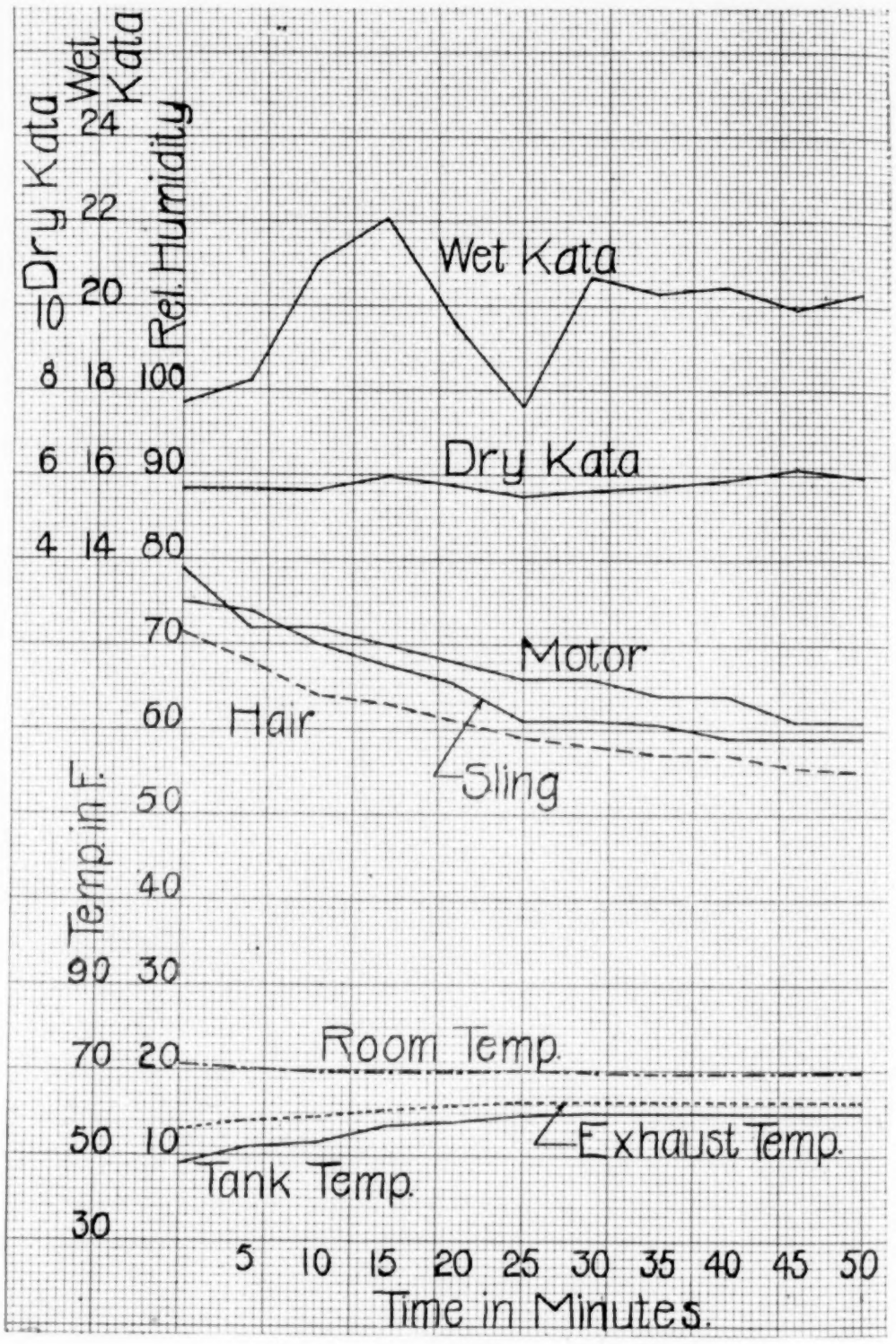

FIG. 3.—Test 3, dehumidifying. Tank water at initial temperature of 48° F. Ordinary tap water used. Test stopped on reaching approximate equilibrium.

TEST 3.—Using ordinary tap water in the tank of the White machine, it was desired to see how quickly and to what extent the room could be brought to ordinary conditions. Test 3 was accordingly started with a relative humidity of

72 per cent., and the tank water at 48° F. Dehumidification occurred slowly but with regularity until the tank water reached 59° F., at which point equilibrium was gradually being reached.

tinually adding snow and withdrawing water. The run was started as soon as a temperature of 32° F. was reached in the tank, and at the same time the gas furnace was lighted and regulated to keep the temperature of the room

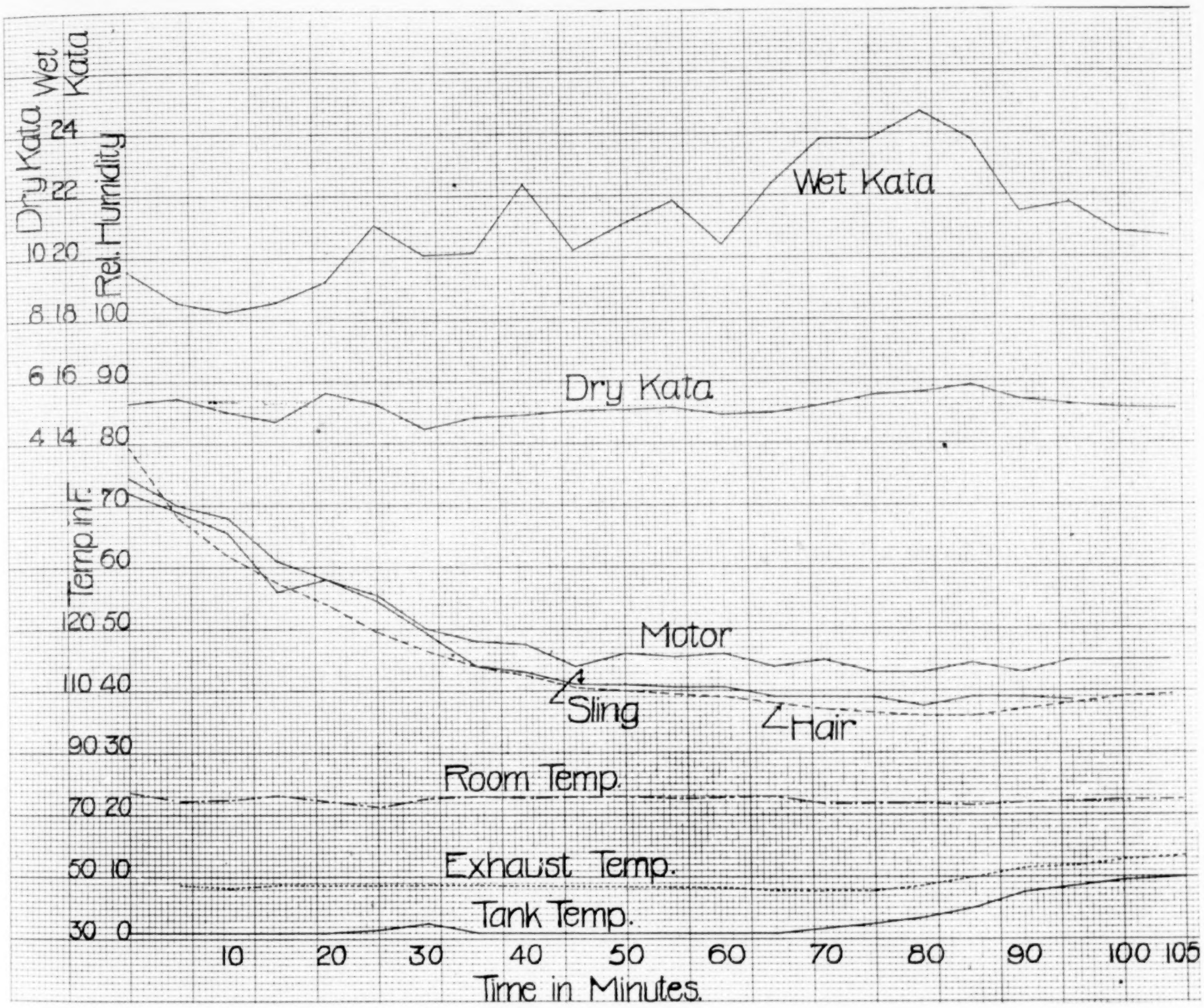

FIG. 4.—Test 4, dehumidifying. Tank water kept at 32° F. for 60 minutes, then allowed to rise to show corresponding rise in relative humidity. Note that exhaust temperature and relative humidity do not rise for some minutes later.

TEST 4.—For use during hot and humid summer days, a machine of this type is called upon to reduce humidity and to keep it at a predetermined figure. To exaggerate conditions prevailing on disagreeable and uncomfortable summer days, the relative humidity of the room was rapidly raised by running the machine for a few minutes with hot water, then emptying it quickly, and refilling with cold water and snow. This mixture gave a tank temperature of 32° F., which was maintained for the first sixty minutes of the test by con-

as nearly constant as possible. Without some source of heat, it is impossible to dehumidify rapidly and at the same time keep up the room temperature to ordinary conditions. The rate of dehumidification is best shown by superimposing the steeper curves of this test on the more gradual ones of Test 3. In order to observe the rise in relative humidity after the equilibrium point was approximately reached, the tank temperature was allowed to increase, and at the same time the gas furnace was turned down lower.

TEST 1.—FEB. 15, 1922

Humidifying

Barometer = 30.12 inches.
Wet kata factor = 521.
Dry kata factor = 548.

Tank Temperature	Relative Humidity							Kata Thermometers				Exhaust Air		Time
	Motor			Sling			Hair							
°F.	W.	D.	%	W.	D.	%	%	Secs. W.	Cooling Power	Secs. D.	Cooling Power	W.	D.	P.M.
106.0	58.0	72.0	42	58.5	72.0	43	37	22.5	23.17	111	6.04	—	—	2.00
102.5	58.5	72.5	42	—	—	—	—	21.0	24.82	90	7.01	—	—	2.05
—	—	—	—	—	—	—	—	21.0	24.82	103	6 38	—	—	2.10
88.0	65.0	74.0	61	65.0	74.0	61	53	27.08	19.25	123	5 60	86.0	86.9	2.15
86.0	69.0	75.0	74	69.0	74.5	76	81	27.08	19.25	123	5.60	86.0	86.9	2.15
82.0	70.0	75.0	78	69.5	75.0	76	82	30.2	17.25	124	5.56	77.9	80.6	2.25
78.0	70.0	75.0	78	69.5	75.0	76	85	30.6	17.05	113	5.96	75.2	77.0	2.30
76.0	70.0	75.0	78	69.0	74.0	78	81	32.1	16.24	119	5.74	73.4	75.2	2.35
74.0	69.5	75.0	76	69.0	74.0	78	79	—	—	105	6.29	71.6	73.4	2.40
72.0	69.0	75.0	74	68.0	74.0	74	78	30.8	16.92	109	6.12	70.7	72.5	2.45
71.0	68.5	74.5	74	68.0	73.5	75	77	29.2	17.84	105	6.29	69.8	71.6	2.50
70.0	68.0	74.0	74	67.5	73.0	75	76	28.2	18.48	96	6.71	68.9	70.7	2.55
69.0	68.0	74.0	74	67.0	73.0	73	75	27.5	18.86	97	6.66	68.0	69.8	3.00

TEST 2.—FEB. 16, 1922

Humidifying

Barometer = 29.51 inches.
Dry kata factor = 521.
Wet kata factor = 548.

Tank Temperature	Relative Humidity							Kata Thermometers				Exhaust Air		Time
	Motor			Sling			Hair							
°F.	W.	D.	%	W.	D.	%	%	Secs. W.	Cooling Power	Secs. D.	Cooling Power	W.	D.	P.M.
154	52.0	68.0	31	50.0	67.0	26	27.0	25.3	21.68	86.5	6.03	—	—	2.35
122	70.0	74.0	82	70.0	73.5	84	80.0	35.6	15.4	115.0	4.53	107.6	108.02	2.40
108	73.0	75.0	91	72.5	74.5	91	93.0	36 0	15.22	119.0	4.375	99.5	99.5	2.45
95	72.5	75.0	89	71.5	74.5	86	90.0	37 5	14 61	109.0	4.78	89.15	89.6	2.50
89	72.0	75.0	86	71.5	74.5	86	87.5	36.5	15.0	109.0	4.78	84.2	85.1	2.55
83	70.5	74.5	82	70.0	74.0	80	84.0	35 5	15.44	106.0	4.82	79.7	81.5	3.00

TEST 3.—FEB. 16, 1922

Dehumidifying

Barometer = 29.51 inches.
Dry kata factor = 521.
Wet kata factor = 548.

Tank Temperature	Relative Humidity							Kata Thermometers				Exhaust Air		Time
	Motor			Sling			Hair							
°F.	W.	D.	%	W.	D.	%	%	Secs. W.	Cooling Power	Secs. D.	Cooling Power	W.	D.	P.M.
58.0	63.0	70.0	68	62.0	69.5	65.5	61.0	30 9	17.72	92.0	5.67	55.4	56.1	3.10
57.0	63.5	70.0	70	62.5	69.5	67.5	63.0	30.0	18.26	92.0	5.67	56.3	58.1	3.15
53.0	64.0	70.0	72	63.0	69.5	70.0	64.0	26.0	21.08	92.5	5.64	57.2	59.0	3.20
52.0	65.0	71.0	72	64.5	70.0	74.0	68.0	25.8	22.1	87.0	5.99	58.1	60.8	3.25
48.0	67.0	71.5	79	66.0	71.5	75.0	71.5	28.0	19.56	91.5	5.73	59.0	61.7	3.30
59.5	62.5	70.0	66	61.5	70.0	61.0	59.0	31.1	17.61	94.5	5.51	59.9	62.6	3.35
60.0	62.5	70.0	66	61.0	69.5	61.0	58.0	26.4	20.78	93.0	5.61	59.9	62.6	3.40
60.0	62.0	70.0	64	60.5	69.0	60.5	57.0	27.0	20.3	91.0	5.725	59.9	62.6	3.45
60.0	62.0	70.0	64	60.0	69.0	59.0	57.0	26.8	20.45	88.6	5.88	59.9	62.6	3.50
60.0	61.5	70.0	61	60.0	69.0	59.0	55.5	27.5	19.94	85.0	6.14	59.9	62.6	3.55
60.0	61.5	70.0	61	60.0	69.0	59.0	55.0	27.0	20.3	87.0	5.99	59.9	62.6	4.00

TEST 4.—FEB. 16, 1922

Dehumidifying

Barometer = 29.51 inches.
Dry kata factor = 521.
Wet kata factor = 548.

Tank Temperature	Relative Humidity							Kata Thermometers				Exhaust Air		Time
	Motor			Sling			Hair							
°F.	W.	D.	%	W.	D.	%	%	Secs. W.	Cooling Power	Secs. D.	Cooling Power	W.	D.	P.M.
32	71.5	77.5	74.5	70.5	77.0	72.0	79.5	28.0	19.58	98.5	5.29	—	—	4.33
32	68.0	75.0	70.0	67.0	74.0	69.0	68.0	29.5	18.58	95.4	5.47	45.5	47.3	4.38
32	67.5	75.0	68.0	66.5	74.5	65.5	62.0	30.0	18.27	103.5	5.04	44.6	46.4	4.43
32	66.5	76.0	61.0	66.0	77.0	65.0	57.5	29.5	18.58	110.0	4.74	45.5	47.3	4.48
32	65.0	75.0	58.0	64.0	74.0	58.0	54.0	27.5	19.23	92.3	5.65	45.5	47.3	4.53
33	63.0	73.5	55.5	61.0	71.5	54.5	49.5	26.0	21.07	98.5	5.29	—	—	4.58
35	63.5	76.0	50.0	62.0	75.5	49.5	46.5	27.0	20.1	117.0	4.455	45.5	47.3	5.03
32	63.0	76.0	48.0	62.0	76.0	44.0	44.0	25.0	21.9	108.0	4.83	46.4	47.3	5.08
32	62.5	75.5	47.5	61.5	76.0	43.0	42.5	24.5	22.37	106.0	4.92	—	—	5.13
32	62.0	76.0	44.0	61.0	76.0	41.0	40.5	27.0	20.27	103.0	5.06	—	—	5.18
32	62.5	76.0	46.0	61.0	76.0	41.0	40.0	26.0	21.08	102.0	5.11	—	—	5.23
32	62.5	75.5	45.5	60.5	75.5	40.5	39.5	25.1	21.81	101.0	5.16	—	—	5.28
32	62.5	76.0	46.0	60.5	75.5	40.5	39.0	26.8	20.42	106.0	4.91	42.8	46.4	5.33
32	62.0	76.0	44.0	60.5	76.0	39.0	38.0	24.5	22.36	104.5	4.99	42.8	45.5	5.38
—	61.0	74.5	45.0	58.0	73.0	39.0	37.0	23.0	23.82	100.0	5.21	41.9	45.5	5.43
35	60.0	74.0	43.0	58.5	73.5	39.0	36.5	23.0	23.82	94.3	5.54	41.9	45.5	5.48
37	60.0	74.0	43.0	58.0	73.5	37.5	36.0	22.2	24.7	92.3	5.65	43.7	47.3	5.53
40	60.0	73.5	44.5	58.0	73.0	39.0	36.0	23.0	23.82	89.0	5.86	46.4	50.0	5.58
45	60.0	74.0	43.0	59.0	74.0	39.0	37.0	25.5	21.5	96.5	5.40	49.1	52.7	6.03
47	60.5	74.0	45.0	59.0	74.5	38.5	38.0	25.2	21.78	99.5	5.24	50.0	53.6	6.08
49	61.5	75.0	45.0	—	—	—	39.0	26.3	20.82	101.5	5.14	51.8	55.4	6.13
50	61.5	75.0	45.0	—	—	—	39.5	26.5	20.7	102.0	5.11	52.7	56.3	6.18

Summary

From these tests it will be seen that a portable air conditioning machine is well adapted to demonstrations and study of variations in relative humidity and temperature. Experimental demonstrations such as these, in which students take part, can easily be amplified to include physiological studies on the effect of temperature, humidity, carbon dioxide, etc.

EXPERIMENTAL OBSERVATIONS UPON THE RELATION BETWEEN ATMOSPHERIC CONDITIONS AND THE PRODUCTION OF FATIGUE IN MINE LABORERS

(Continued)

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Method of Tests

The methods proposed and adopted were:

1. To register the output of work by suitable ergometers under various atmospheric conditions to be found on the surface and at several places underground.

2. To take an ergographic record of each subject before and after each day's work, exhausting one small group of muscles, such as the flexor muscles of the middle finger as previously explained, and by this means to estimate the degree of general fatigue produced by the work.

3. To find to some extent the physiological effects on the subjects, by taking skin temperature, body temperature (by mouth), and loss of weight during part of the tests at least.

4. Atmospheric conditions were determined by wet and dry bulb temperatures, by wet and dry kata-thermometer readings, and also by general observations as to air motions, etc.

It was our intention to have, say, two natives working on ergometers, and to spend, perhaps, a week in each of four or five different positions, commencing on the surface and progressing from the best to the worst conditions underground, then reversing the order of progression and finishing up again on the surface. The set of tests in the reverse order was intended to be a check on the effects of training or practice. After this, comparative tests, such as tests of effects of rest and of a meal during working hours, were to be carried out in the best and worst places underground. The same series was intended to be carried out with a second pair of natives, and, if time permitted, with a third pair, to eliminate effects of individual idiosyncrasies. As will appear later, however, events occurred which limited the tests to one pair of subjects.

Choice of Apparatus

In the previous tests carried out by the Sanitation Department, Rand Mines, there was a good deal of evidence, such as loss of weight and signs of fatigue, to show that the work involving the greatest expenditure of energy and production of fatigue was that of the hammer boy, and therefore an ergometer on which this class of work could be registered was highly desirable.

It was thought at first that an ergometer to register work similar to hand drilling could be made with a very stout helical spring fixed at one end in a rigid frame, and provided at the other end with an anvil piece which would re-

ceive the impact of the blow from the jumper; the deflection of the spring would give an indication of the energy in each blow—to be determined exactly by calibration—the deflections to be recorded by a pencil connected to the anvil piece and bearing up against a moving roll of paper. It was found after a few trials that the recoil from a spring with a suitable deflection was so great that it made normal hammering impossible; and, moreover, that it would be impossible to get a smooth record from a pencil attached to such a spring. So the spring method was abandoned.

Another method was tried with better success, and was ultimately adopted. The ergometer finally adopted is shown in Figure 4. A is a steel disk about 3/16 of an inch thick with a boss B to receive the jumper. This forms the cover of a shallow cast steel vessel C and is clamped by a ring D with bolts. Vessel C is connected by a pipe to an engine indicator E; a stand-pipe F is joined by a T-piece to the connecting piece at the lower end and to a water reservoir G at the upper end, a disk with a small orifice H about 1/32 of an inch in diameter being interposed in the stand-pipe a few inches from the lower end. The whole was filled up with boiled water, the air escaping from a plug J in the steel disk. K is a tripod frame fitted with a tube to guide the jumper. When a blow from the hammer is communicated by the jumper to the disk, the lat-

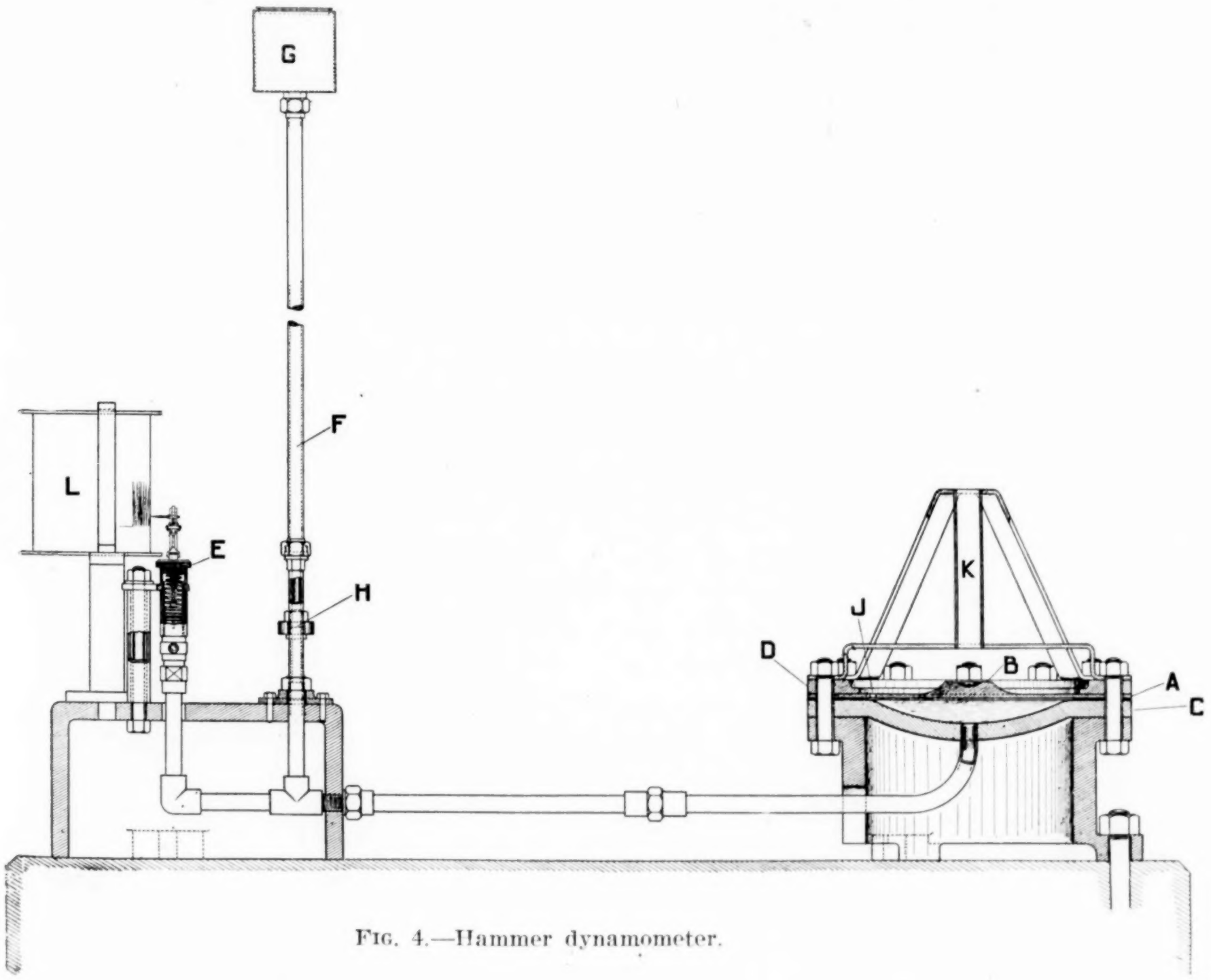

FIG. 4.—Hammer dynamometer.

ter is deflected inward to the vessel and an impulse accompanied by *displacement* passes along the pipe to the indicator, the piston of which is displaced upward by an amount depending on the violence of the hammer blow. There is a rebound of the disk and, consequently, of the indicator piston; then they both reach equilibrium again in a small fraction of a second. As the piston takes a small film of water with it at each stroke, this loss is made up from the reservoir G, which has the additional function of keeping a steady pressure inside the machine. The small orifice H prevents the impulse from the hammer disk from losing its energy in the stand-pipe. The indicator pencil is lightly held by elastic bands against a roll of paper L moved by a machine specially made for the purpose. Figure 5 shows the general arrangement with the position of the native.

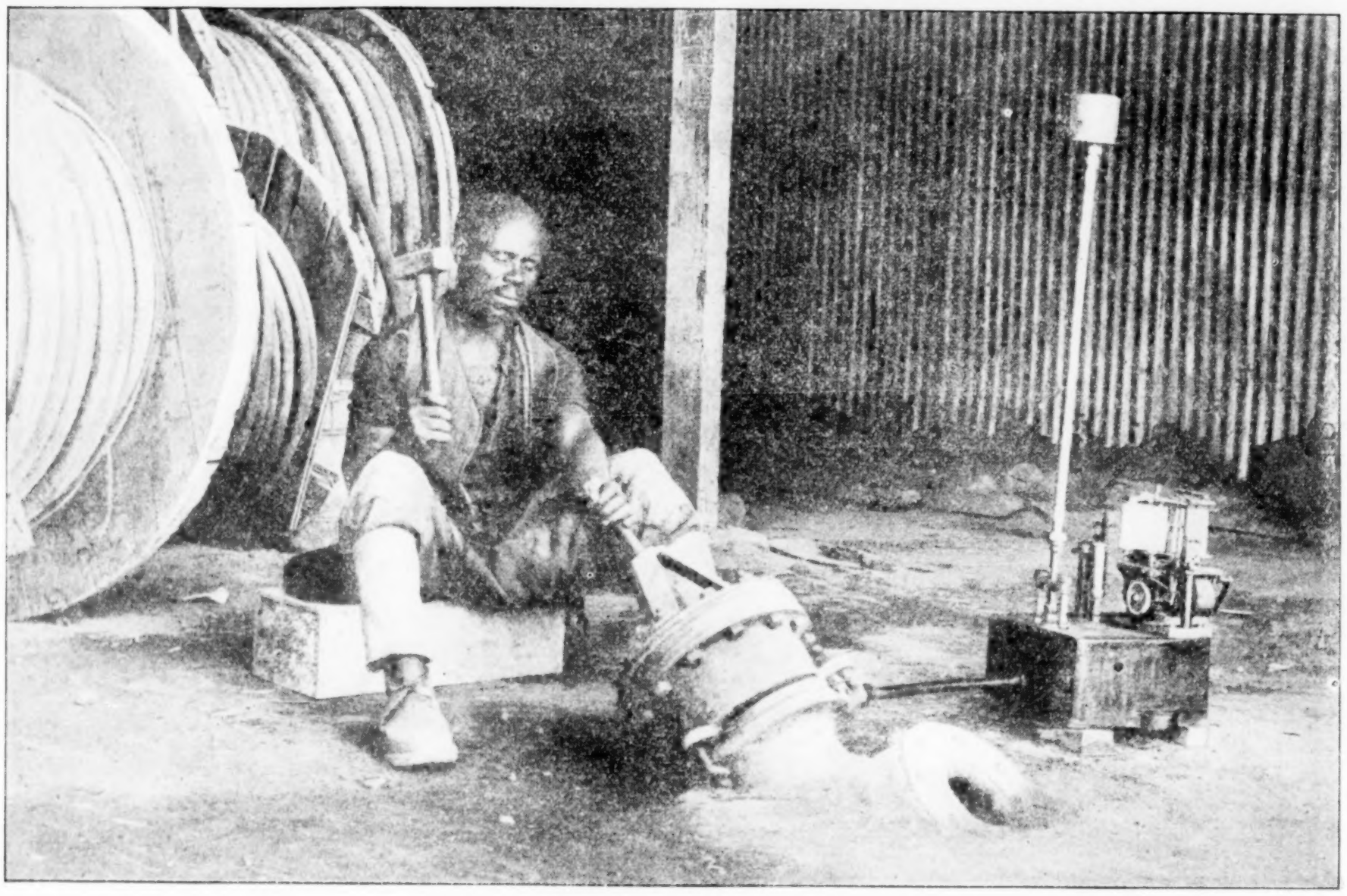

FIG. 5.—General arrangement of hammer dynamometer with position of native.

Figure 6 shows a sample of the record taken. The whole line including the rebound was utilized, as this gave not only greater amplitude but better definition, the zero being somewhat indefinite, especially as the pencil was chiseled to avoid frequent sharpening. The calibration was performed by drop-

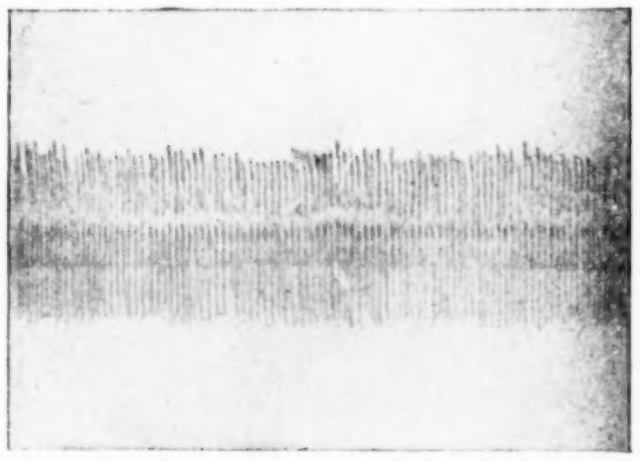

FIG. 6.—Sample hammer dynamometer record.

ping, from various heights, a weight equal to that of the hammer used, making at the same time an indicator record. A curve was then plotted giving the relations of the indication to the energy of the blow, the latter being calculated from the weight and height through which the weight fell.

The indication seemed to obey no simple law; on simple theoretical grounds, it should have varied with the square root of the energy of blow, and this it did approximately. Momentum seemed to play some part, as an 8-pound weight falling 2 feet did not give the same indication as a 4-pound weight falling 4 feet, though the energy is the same in each case. The dead weight of the jumper, and to some extent of the disk itself, would, of course, be a factor in the case. The calibration was therefore carried out with a weight equal to the hammer used, about 4.34 pounds, and with the same weight of jumper as was used during the tests.

To prevent the stresses due to impact from producing brittleness in the anvil disk with danger of cracking and change of indication, the disk was changed and annealed after being used for a week, a calibration being made at the beginning and end of each week. The jointing ring between the disk and the flange of the vessel was also renewed every week.

Unfortunately, it was found that the indication was liable to variation, due to many factors besides the energy of the hammer blow, such as the viscosity of the water which varied with the temperature, the condition of the jointing ring, any slight obstruction in the connecting pipe, the presence of small bubbles of air, the friction of the indicator piston, etc. As the indication was small with a strong spring in the indicator, a light spring had to be used which made the effect of friction of the indicator quite appreciable.

It was only by extreme care and attention that these factors could either be eliminated or kept constant during a week's working tests and the calibrations, and as the observer had his attention fully occupied in taking readings during the tests and attending to the recording machine, etc., it is not surprising that errors crept in, which rendered a day's or even a week's tests utterly unreliable, and consequently necessitated the discarding of the results.

Another drawback to this form of ergometer, which would apply to *any form* of machine registering hammer blows, is the fact that it has to withstand the shock of over 14,000 heavy blows each working day; consequently, its construction has to be very robust and it must be bolted firmly to a solid foundation. The setting up, dismantling and calibrating of this machine each week occupied a considerable amount of time so that it was possible to get only four working test days each week.

The second ergometer, or "rotary" machine, was essentially a band-brake dynamometer driven like a winch. Figure 7 shows a section of this machine. A is the brake pulley driven through the spur gearing B from the driving crank; C is a leather belt hung over the pulley. In order to eliminate the errors and the trouble of reading a spring balance on the light tension end of the belt, weights W and w were used, one on each side, and the equilibrium of the belt obtained by making the friction self-adjusting. This feature was obtained by studding one-half of the belt with metal rivets, the heads projecting inside and making contact with the pulley instead of the belt. If the friction was too great, the

belt was pulled over more onto the riveted portion, the friction being thereby decreased; if the friction was too small, the belt automatically slipped back, making more leather contact with consequent increase in friction. To avoid having to correct for variations due to the position of the belt, the latter was balanced, little lead weights being attached on the outer surface of the unrivetted portion to balance the weight of the rivets, the ends of the belt being laced together underneath as shown at D, and the weights W and w suspended by a light band of cotton webbing E. A revolution counter on the driving spindle completed the essentials of the machine. The machine was fixed in position by clamping to a post shown at F. The observer had only to note the weights and to take periodical readings of the revolution counter. Every revolution represented so much work done for a certain net pull on the brake pulley, or for a certain difference in the weights.

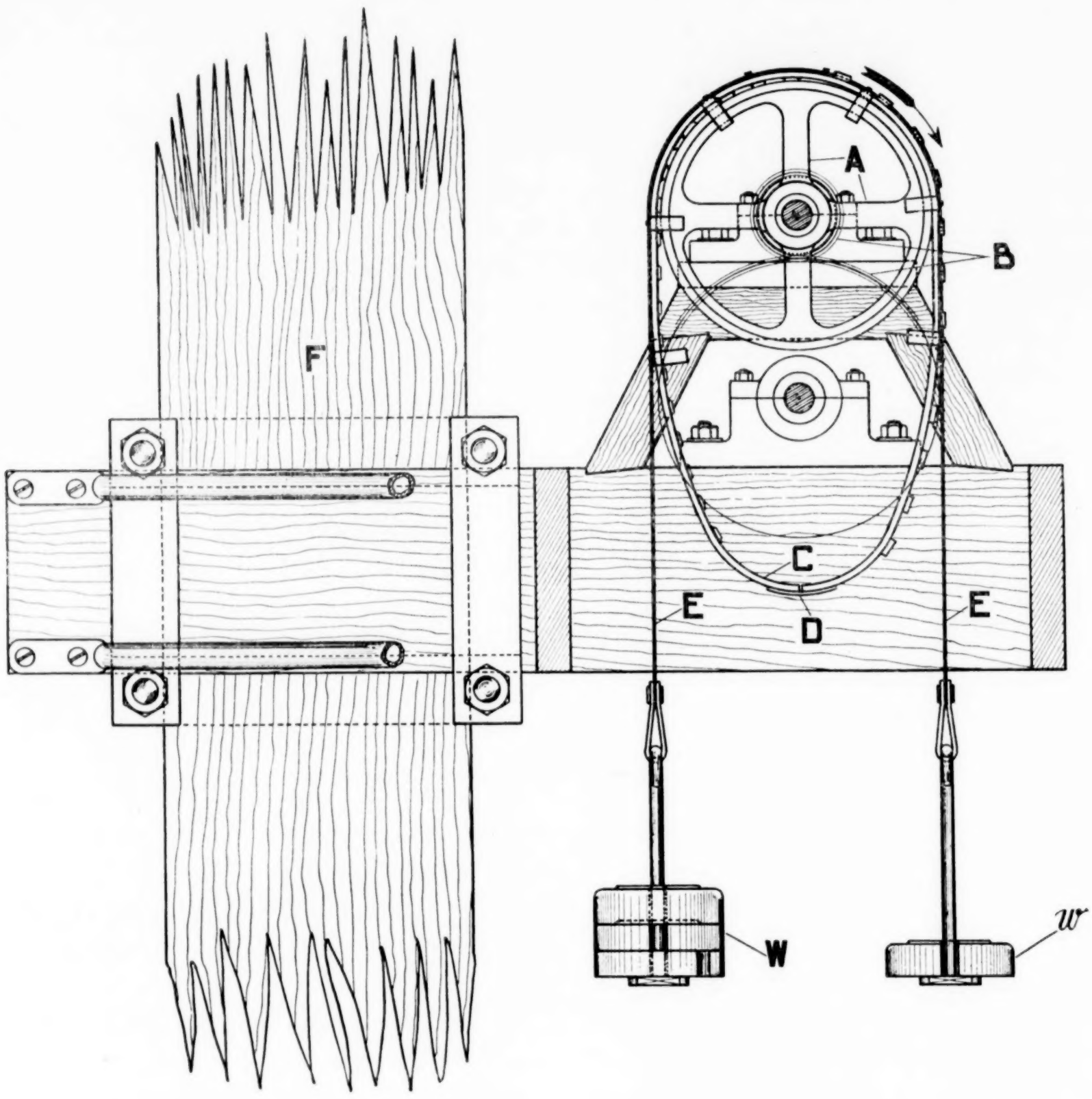

FIG. 7.—Rotary ergometer.

The machine was calibrated by substituting for the driving crank a narrow

wooden pulley of the same radius, and driving the machine by pulling a cord off this driving pulley, the pull being read on a spring balance. The calibration followed very closely the ordinary straight line law for machines giving mechanical advantage:

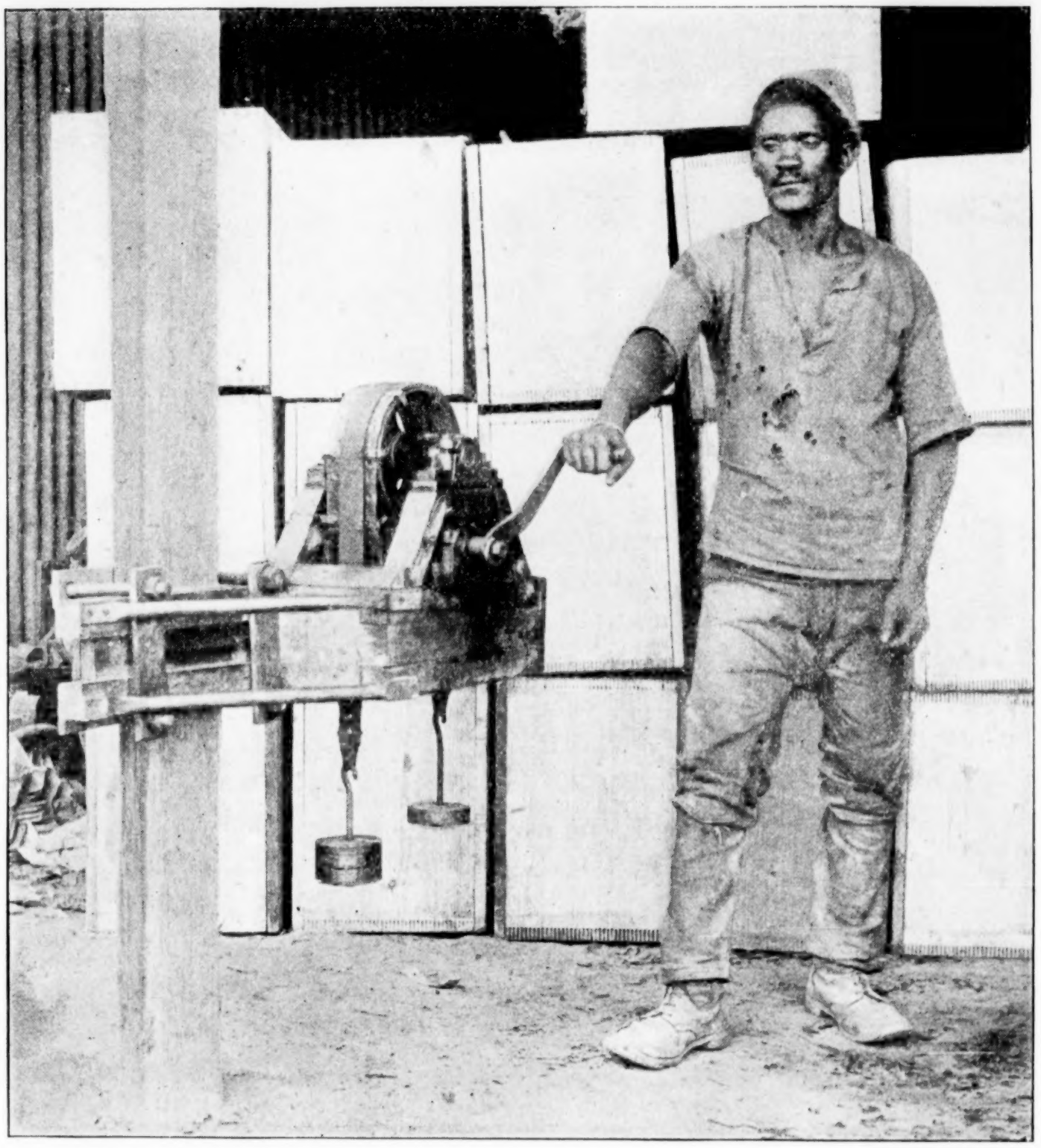

FIG. 8.—General view of rotary ergometer with native.

$$P = a\,(W - w) + b$$

where P = force at driving handle
W and w are the large and small weights
a and b are constants

Figure 8 gives a general view of this machine with operator, and shows the method of fixing the machine to a wooden post. The advantages of this machine are its simplicity, accuracy, robustness, reliability, the very little attention it requires, and the ease with which results can be computed. It does not have to withstand heavy strokes like the hammer machine. The winding action is much less wasteful of human motion and energy than the hammering action, hence the results follow more closely the human energy expended. Care, however, has to be exercised in determining the weights to give approximately the "optimum effort and speed." The drawbacks of the machine are that

it does not give a continuous record, that it measures work of a purely unskilled nature, and may not give a correct estimate of capacity for doing work, such as hand drilling, where skill is of considerable importance.

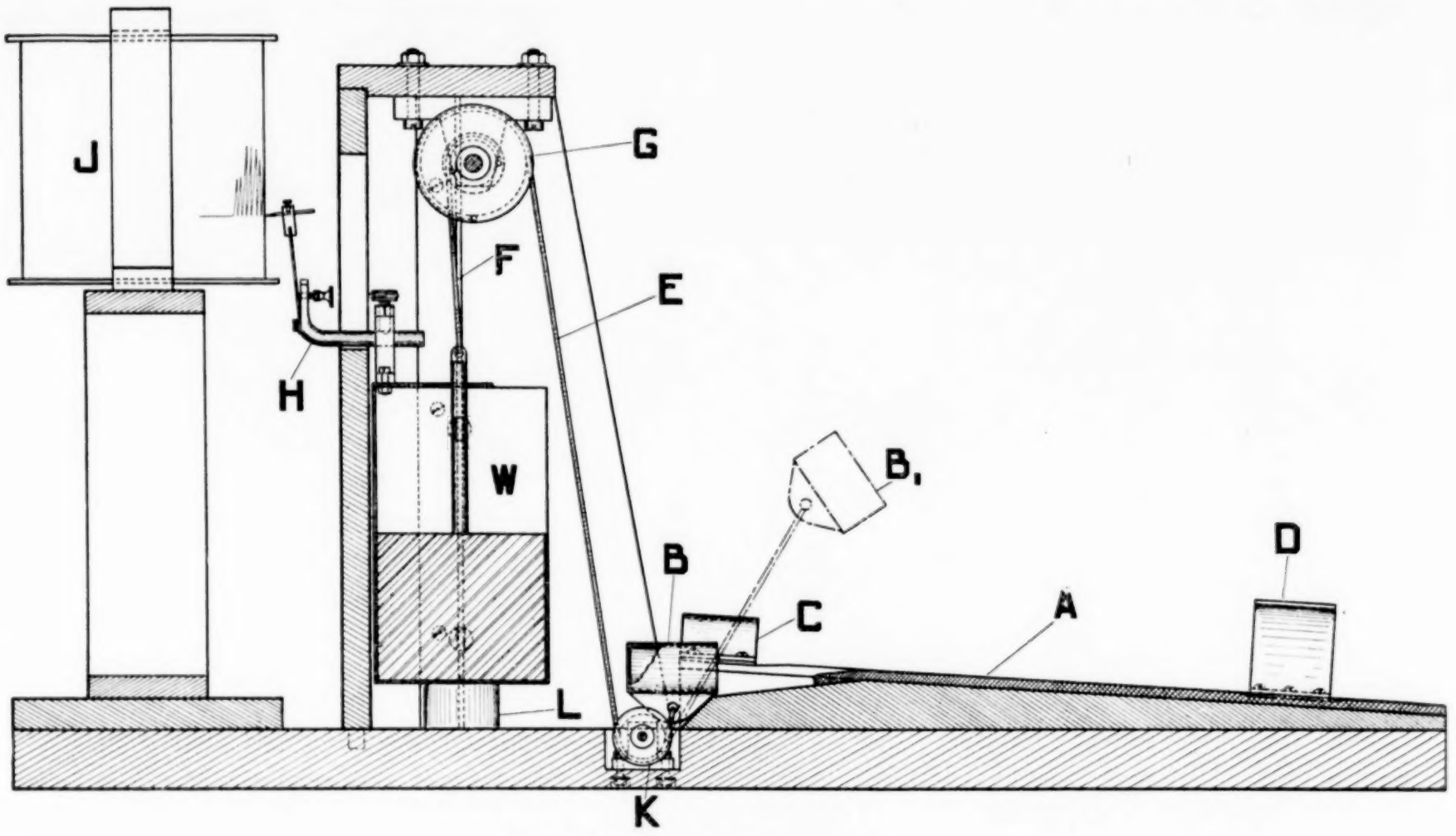

FIG. 9.—Finger ergograph.

The advantages of the hammer machine over the rotary machine are that it gives a complete record of the day's work, the energy of each blow, and the rate of blows, and shows up any variation throughout the test and any pauses due to fatigue or muscle stiffness; furthermore, it simulates very closely hand drilling, *the type of work which causes the greatest amount of fatigue.* The work being semi-skilled, it brings in the nervous-control factor which is affected by fatigue, thus producing bad hitting or even missing, etc. The computation of results, however, unlike the computation with the rotary machine, was a long, tedious, eye-straining and laborious process.

The finger ergograph adopted is shown in section in Figure 9. It was designed to be used in conjunction with the recording machine used in the hammer machine, and is on the same principle as Mosso's ergograph. The hand and arm are laid on a board A covered with felt, the index and third fingers being placed in straps C to prevent movement, and the middle finger being inserted in a metal clip B which is attached by cords E, E to a weight F. To bring the movements well within the scope of the paper roll used for the hammer machine, the movement of the weight was reduced by a 2 to 1 pulley gear G. The pencil attachment H is fixed to the weight and pressed against the paper roll J. K is simply a jockey pulley to alter the direction of the pull of the cord, and L is a rubber buffer to receive the weight as it comes down after each stroke. Figure 10 gives a picture of the ergograph with the subject's hand in position.

At first, a machine was used in which the hand, all but the index finger, was clasped in a vertical plane, the index finger being moved in the same plane raising a weight. This machine was

very light and convenient in some ways, but the action of moving the index finger away from the other fingers is one over which there is not good control and which requires more mental concentration and intelligent use than the flexing of the middle finger. It should be explained here that to make the ergograms strictly comparable, the maximum effort of which the muscles are capable should be exercised at each movement, and it was difficult to get the natives to appreciate that this was wanted. A set of muscles not well controlled requires much more mental concentration to give the maximum effort. Hence the type of machine in which the middle finger was flexed was afterwards adopted, and gave better results. Even this machine, as experience has taught us, is open to grave objections, especially when used with natives. With intelligent men, good results can be obtained when the muscles are properly flexed.

It will be noted that in flexing the middle finger there are three joints involved—the knuckle joint and two others on the finger itself. In proper use of this ergograph the maximum effort and travel should be made by all three joints, the knuckle giving the most travel and requiring most effort, the next joint of the finger giving less travel and less effort, and the first joint of the finger giving very little motion indeed. The tendency of the native was to make the motion one chiefly from the middle joint which required much less effort and which produced much less fatigue —a movement which the subject was sometimes capable of carrying on indefinitely. Moreover, it was impossible to distinguish from the ergogram whether the later movements were partial movements of all three joints or more or less complete movements of the middle joint. The investigators would, if carrying out a similar investigation, make radical changes in the ergograph, and would restrict the movement to one joint only. Electrical, instead of voluntary stimulation of the muscles would, of course, have eliminated the variations due to lack of concentration, etc., but the apparatus required is expensive, complicated, and not suitable for the conditions underground. For these reasons fatigue was estimated not only by ergograph but by observation of physical signs, falling off in rate of work, etc.

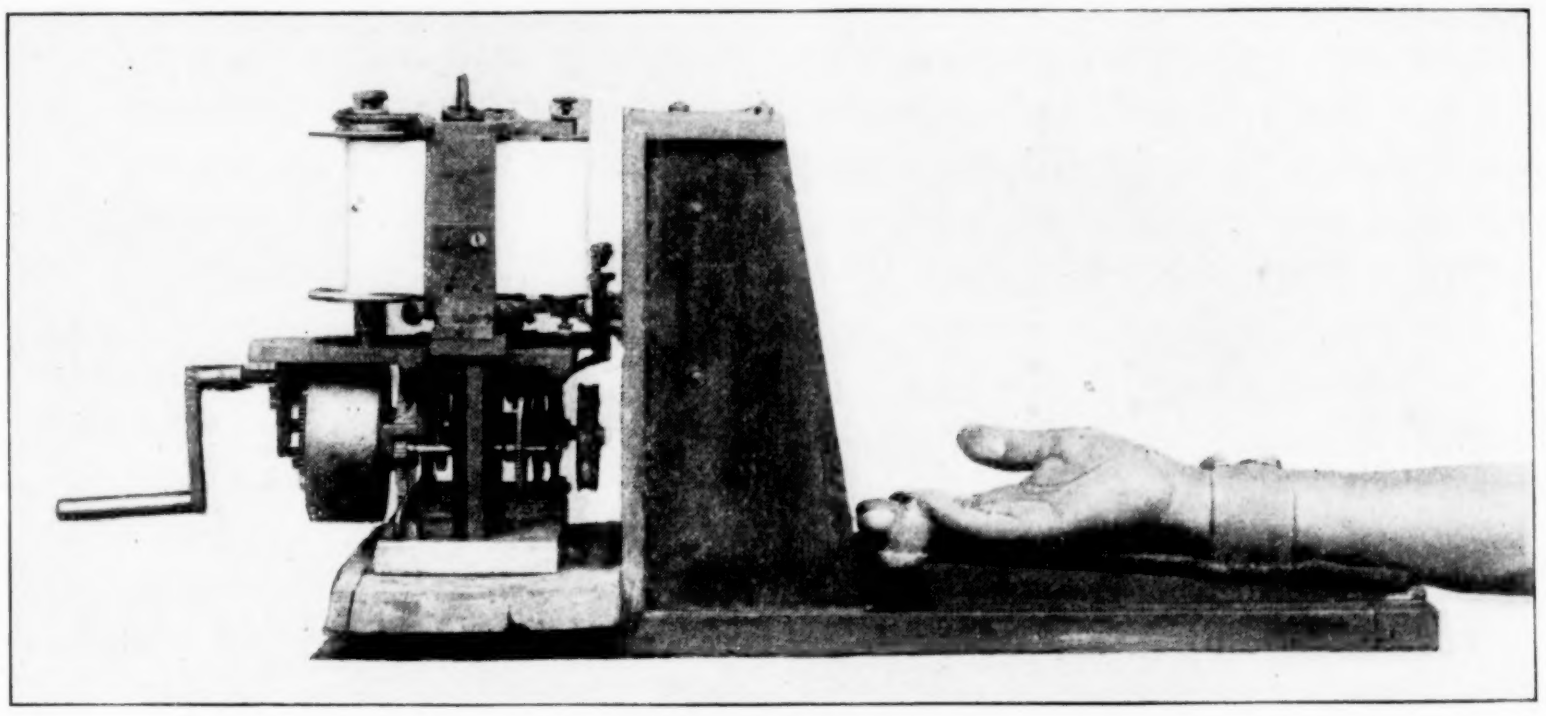

FIG. 10.—Ergograph with subject's hand in position.

Subjects of Test

The natives were chosen for us by Mr. Deakin, Underground Native Supervisor, Village Deep Mines, to whom was explained what qualities were wanted, and who interpreted to the natives what they were required to do. We are indebted to Mr. Deakin, not only for procuring suitable natives, but also for helping on several occasions to make explanations to them and to encourage them to work steadily and cheerfully.

The hammer boy was a Xosa, about 40 years of age, tall, well formed and strong, with finely developed muscles. He possessed alertness, intelligence and initiative well above the average native. His average net weight was about 10½ stones. He was a splendid worker and well trained in the use of the hammer and jumper. His tendency was to keep up a steady rate of hammer blows with almost clock-like precision at a rate of about 61 to 63 blows per minute, the energy of the blow only falling off when considerable fatigue or discomfort set in.

The rotary boy was a Basuto, aged about 35 years, short and sturdy, with an average net weight of about 8¾ stones. He was of rather low intelligence, somewhat dreamy, and without initiative

Both boys were fresh from a six months' holiday; they were free from disease, and had no sickness during the period of tests; they seemed to be of steady, regular habits, and only on few occasions did their condition seem to be affected by incidental factors outside of the working hours. They lived in the compound and had the same rations as the other natives. They usually left the compound about 6 A.M. and returned there about 3 P.M. After some preliminary tests and consultation with mine officials familiar with the work of the natives, it was considered that four hours of continuous work at full capacity was at least as great as the average work performed in actual mining, and this work period was adopted. The observer, native attendant, and test subjects usually went underground from 7 to 7.30 A.M., and after ergograph readings, uncovering and preparation of apparatus, etc., work was generally commenced between 8 and 9 A.M. The test days were usually Tuesday to Friday, Saturday and Monday being required for calibration and changing the outfit to another station.

Working Stations

The stations were chosen, after katathermometer readings had been taken in several places, with a view to giving widely different values of cooling power, consistent with convenience of access, etc., and non-interference with mining work going on, also at sufficient distance from any blasting operations. The positions chosen were:

Surface

1. Cable shed in store yard.

Underground

2. 19 Station near Turf Shaft, depth 4,550 feet below datum level.
3. Stope J. 20 (disused) depth about 4,500 feet, 75 feet from station.
4. 23 Drive East at blind end, depth 5,125 feet, 2,500 feet from station.
5. 24 Drive West at blind end, depth 5,260 feet, 2,500 feet from station.

Depths are given below datum level which is 6,000 feet above sea level.

Results of Tests

Table 3 gives the cooling power (wet and dry), the wet and dry bulb temperature readings, output of work

of hammer and rotary machines, notes on fatigue, clothing, and condition as to perspiration, for the whole series of tests. Figure 11 presents the output and "kata" readings in diagrammatic form. Table 4 gives the weight lost, and mouth and skin temperatures during a part of the series, including the worst and best conditions; the values of cooling power are repeated for near reference.

Figure 12 consists of typical curves showing the rate of output of the rotary machine during the working period. Figure 13 gives outline curves of typical finger ergograms taken before and after work in various working stations. Attention is drawn to the fact that in 19 Station (the best working place underground) the areas of ergograms performed after work are larger than those performed before work, indicating that in these cases there was little or no fatigue produced in the working period. The fact that there was little (in some cases no) diminution in output toward the end of the four-hour working period at this station, especially in the case of the hammer boy, seems to confirm this.

Due to irregularity of work diagrams or calibration curves, for which there were several causes, a large proportion of the figures of output of the hammer machine have had to be discarded as unreliable. This was most unfortunate, as this machine was by far the more expensive, not only in first cost and upkeep, but in attention required and trouble caused; moreover, the hammer boy was the better and steadier worker of the two, and his output in the hotter places, when he showed such great fatigue, would have been valuable information.

It should be noted that the figures of output of the rotary machine for the first tests on the surface, although giving accurately the actual work done, do not give a fair measure of the native's capacity. The observers were somewhat misled by his look of languor and mis-

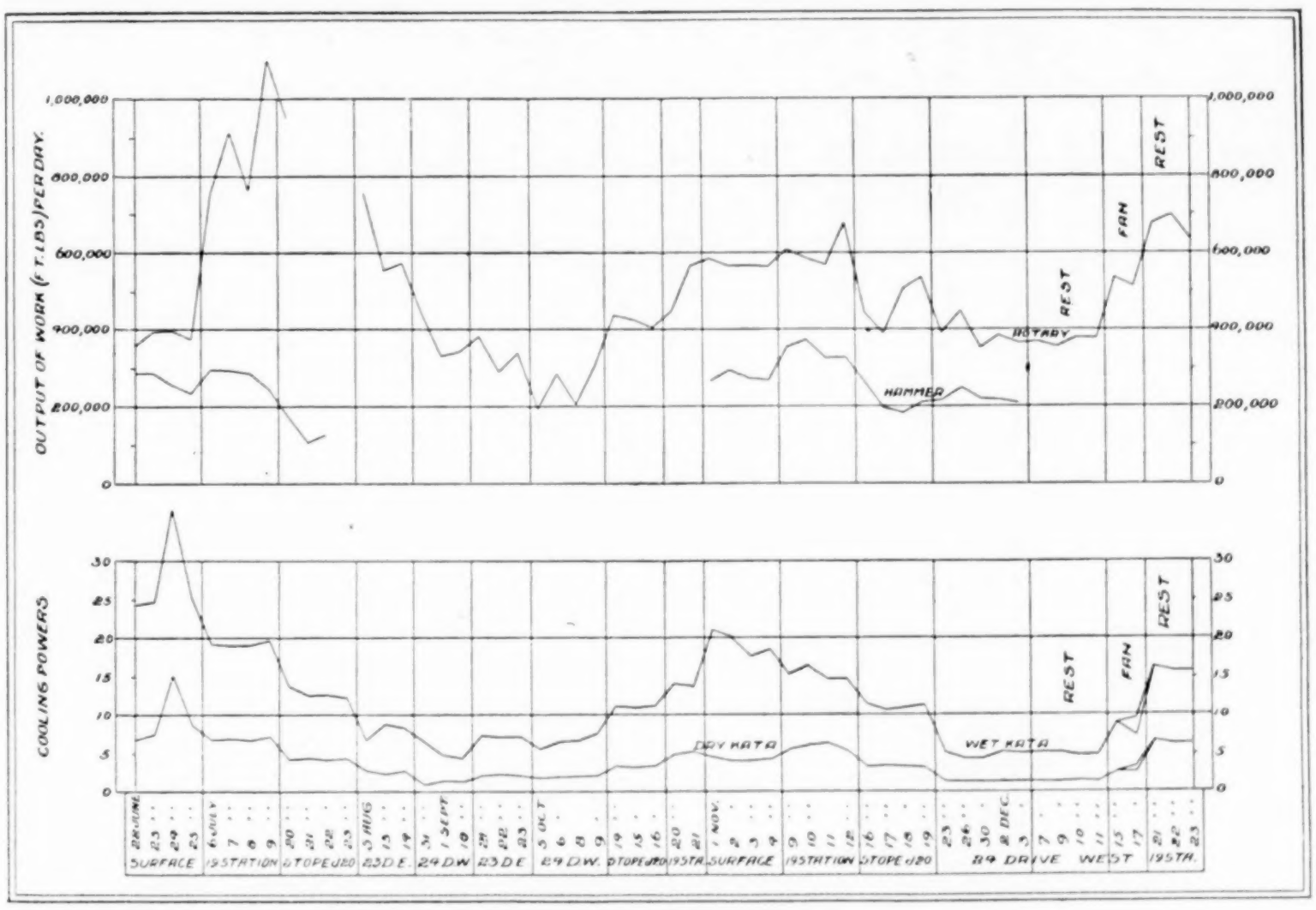

FIG. 11.—Curves showing output of hammer and rotary machines and kata-thermometer readings for work period.

TABLE 3.—KATA-THERMOMETER AND PSYCHROMETER READINGS, OUTPUT OF WORK, AND CONDITION OF SUBJECTS AS TO FATIGUE, CLOTHING, AND PERSPIRATION DURING ENTIRE SERIES OF TESTS

Date[1]	Position	Average Cooling Powers		Psychrometer		Work Done per Day		Fatigue Conditions *After Work*		How Clothed	Remarks
		Dry "Kata"	Wet "Kata"	Dry Bulb	Wet Bulb	Hammer	Rotary	H.B.[2]	R.B.[3]		
		Millicalories per sq. cm. per sec.		*°F.*	*°F.*	*ft. lbs.*	*ft.-lbs.*				
6/22/20	Surface	6.8	24.4	54.3 to 64.7	43.9 to 46	288,000	359,000[4]	slight	very slight	Coats on first hour; afterwards, vests, trousers and boots.	No perceptible sweating; cool.
6/23/20	,,	7.54	24.6	56.0 to 59.0	41.2 to 43.6	288,000	395,000[4]	,,	,, ,,	Same.	Same.
6/24/20	,,	15.1	36.7	37.7 to 48.2	29.0 to 33.4	258,000	396,000[4]	,,	,, ,,	Coats on all the time.	Cold wind blowing.
6/25/20	,,	8.75	25.4	40.3 to 50.8	31.7 to 38.8	234,000	375,100[4]	,,	,, ,,	Coats on two hours.	Quite cool.
7/ 6/20	19 Station	6.8	19.1	62.4	60.2	295,000	753,000	,,	slight	Stripped to waist.	Slight sweating.
7/ 7/20	,,	6.94	19.0	62.6	60.1	292,000	912,000	very slight	,,	,, ,, ,,	,, ,,
7/ 8/20	,,	6.65	19.1	62.7	60.2	288,500	765,000	slight	,,	,, ,, ,,	,, ,,
7/ 9/20	,,	7.2	19.7	62.7	60.6	249,000	1,104,000	very slight	,,	,, ,, ,,	,, ,,
7/20/20	Stope J.20	4.27	13.75	75.2	71.8	178,680	953,000	slight	moderate	,, ,, ,,	Perspiring freely; slight air movement.
7/21/20	,,	4.4	12.5	75.2	71.9	103,000	953,000	,,	,,	,, ,, ,,	Perspiring freely; rotary not working.
7/22/20	,,	4.2	12.5	75.2	71.6	125,000	—	,,	,,	,, ,, ,,	Same.
7/23/20	,,	4.39	12.1	75.4	71.9	—	—	,,	,,	,, ,, ,,	,,
8/ 5/20	23 Drive E.	2.66	6.7	82.4	80.6	—	758,000	moderate	,,	,, ,, ,,	Perspiring very freely; cooling power varies, due to pneumatic drill.
8/13/20	,,	2.48	8.6	81.7	79.0	—	554,000	,,	,,	,, ,, ,,	Perspiring very freely.
8/14/20	,,	2.6	8.4	81.3	78.8	—	570,000	,,	,,	,, ,, ,,	Perspiring very freely; air still.
8/31/20	24 Drive W.	0.935	5.17	88.2	87.8	—	436,000	,,	,,	H. B. stripped to waist; R. B. stripped entirely.	Perspiring very freely.
9/ 1/20	,,	1.39	4.84	87.1	86.7	—	330,000	,,	,,	Both stripped to waist.	,, ,, ,,
9/10/20	,,	1.32	4.35	87.8	87.2	—	340,000	,,	,,	,, ,, ,, ,,	,, ,, ,,
9/21/20	23 Drive E.	2.08	7.32	84.2	82.4	—	380,000	great	great	,, ,, ,, ,,	,, ,, ,,
9/22/20	,,	2.32	7.1	84.2	82.4	—	290,000	,,	,,	,, ,, ,, ,,	,, ,, ,,
9/23/20	,,	2.07	7.04	84.2	82.4	—	336,000	,,	,,	,, ,, ,, ,,	,, ,, ,,
10/ 5/20	24 Drive W.	1.65	5.56	87.7	86.2	—	192,000[5]	extreme	very great	,, ,, ,, ,,	Perspiring very freely. H. B. had to be assisted up to surface.
10/ 6/20	,,	1.92	6.58	86.5	85.3	—	281,000[5]	very great	,, ,,	,, ,, ,, ,,	Perspiring very freely.
10/ 8/20	,,	1.98	6.66	87.1	85.9	—	201,000[5]	great	great	,, ,, ,, ,,	,, ,, ,,
10/ 9/20	,,	2.04	7.58	86.7	85.9	—	301,500	very great	very great	,, ,, ,, ,,	Perspiring very freely; H. B. played out.

10/14/20	Stope J.20	3.32	11.0	78.8	76.7	—	433,000	moderate	moderate	Both stripped to waist	
10/15/20	"	3.11	10.7	79.9	77.6	—	424,000	"	"	" " " "	
10/16/20	"	3.44	11.0	79.6	77.6	—	401,000	great		" " " "	
10/20/20	19 Station	4.9	14.0	68.3	66.7	—	447,750	great	great	H. B. stripped to waist; R. B. armless singlet.	H. B. seemed tired at start; bodies dry, faces moist.
10/21/20	"	5.1	13.7	66.5	65.5	—	567,000	moderate	moderate	Both stripped to waist.	Bodies dry, faces moist.
11/ 1/20	Surface	4.6	21.0	69.8	56.3	264,000	585,000	moderate	slight	Both boys with singlets, trousers and boots.	No perceptible sweating except at armpits.
11/ 2/20	"	4.0	20.0	74.5	56.5	292,000	565,000	"	"	Same.	Same.
11/ 3/20	"	4.12	17.6	74.1	57.9	270,000	568,000	"	"	"	"
11/ 4/20	"	4.22	18.5	73.4	59.0	268,000	562,000			"	"
11/ 9/20	19 Station	5.5	15.3	68.7	65.6	352,500	605,000	slight	"	Both boys stripped to waist.	Slight sweating about face.
11/10/20	"	6.18	16.5	68.8	67.4	370,000	587,000	no signs	"	Same.	" " " "
11/11/20	"	6.22	14.9	69.1	67.4	326,000	568,000	slight	"	"	H. B. appeared less energetic at start.
11/12/20	"	5.47	14.9	68.8	67.7	325,000	673,000	no signs	"	"	Slight sweating, especially about face.
11/16/20	Stope J. 20	3.36	11.35	80.6	78.4	—	441,000	slight	moderate	"	Perspiring fairly freely; slight air movement.
11/17/20	"	3.44	10.5	80.6	78.4	198,000	388,000	"	"	"	Same.
11/18/20	"	3.46	10.6	80.8	78.6	181,000	503,000	"	"	"	"
11/19/20	"	3.25	11.15	80.8	78.6	208,000	533,000			"	"
11/23/20	24 Drive W	1.38	5.05	87.5	86.7	212,500	390,000	moderate	"	"	Perspiring very freely.
11/26/20	"	1.43	4.46	87.8	86.8	245,500	448,000	"	"	"	" " "
11/30/20	"	1.25	4.4	88.0	87.2	219,500	350,000	"	"	"	" " "
12/ 2/20	"	1.27	5.05	88.0	86.8	214,500	383,000	"	"	"	" " "
12/ 3/20	"	1.26	5.0	87.8	87.1	201,500	365,000				
12/ 7/20	"	1.37	5.05	87.8	86.9	—	367,000	"	"	"	Rest at half-time; perspiring very freely.
12/ 9/20	"	1.33	5.1	88.0	87.1	—	356,000	"	"	"	Same.
12/10/20	"	1.38	4.97	87.8	86.8	—	378,000	"	"	"	"
12/11/20	"	1.36	4.95	88.0	86.8	—	374,000				
12/15/20	"	2.48	9.0	86.4	85.7	—	537,000	slight	slight	"	Fan working; rest 20 minutes; half-time.
12/17/20	"	H:3.16 R:2.5	H:9.5 R:7.4	86.4	85.4	—	510,000	"	"	"	Dust samples taken; fan working; no rest.
12/21/20	19 Station	6.64	16.4	68.8	67.7	—	673,200	"	"	"	Rest at half-time; no perceptible sweating.
12/22/20	"	6.05	15.9	69.5	68.3	—	697,500	"	"	"	Same.
12/23/20	"	6.28	15.6	69.8	67.7	—	639,000	"	"	"	"

[1]Arrangement of dates follows the American custom—*i.e.*, month, day of month, year.
[2]H.B. refers to hammer boy.
[3]R.B. refers to rotary boy.

[4]These figures are abnormally low, due to insufficient weight on the rotary.
[5]These figures are abnormally low, due to the belt having been steeped in paraffin, the belt friction being so decreased as to make it incapable of sustaining more than one-third of optimum weight. These figures would have been about 300,000 foot-pounds with adequate weight.

took it at first for fatigue, and consequently did not load up the machine sufficiently to test the native's capacity. Also, during the 5th, 6th and 8th of October in 24 Drive West, the output is low for a similar reason. In this case the belt, which had become tacky, was cleaned by soaking in paraffin, with the result that the friction was too small, and was incapable of supporting more than about a third of the optimum weight. When this defect was remedied, the work output rose from 201,000 to 301,500 foot-pounds, which latter figure should be taken as approximately the correct output.

On examination of Table 3, or Figure 11 which is its diagrammatic equivalent, one of the first things to strike one is the disparity of the outputs of hammer and rotary machines. It is well known that hammering, whether by engine or human power, is a very inefficient operation, there being a great absorption of energy by molecular friction in the parts giving and receiving the blow; moreover, considered from the point of view of physical energy, the action of wielding a hammer is a most inefficient one.

With regard to the amount of work capable of being performed, it is stated in some engineering pocket books that a man can, by winding a winch, per-

TABLE 4.—LOSS OF WEIGHT, AND SKIN AND MOUTH TEMPERATURES DURING TESTS

Date	Position	Cooling Power		Loss of Weight		Skin Temperature [1]		Mouth Temperature [1]	
		Dry "Kata"	Wet "Kata"	H.B.	R.B.	H.B	R.B.	H.B.	R.B.
				lbs	*lbs.*	°*F.*	°*F.*	°*F.*	°*F.*
Sept. 10	24 Drive W.	1.32	4.35	6.44	6.88	94.6	94.6	97.8–100.1	97.7–100.5
" 21	23 Drive E.	2.08	7.32	5.0	5.88	92.5	92.9	97.9– 99.4	98.0– 99.5
" 22	" " "	2.32	7.1	4.44	5.44	91.4	91.8	97.8– 99.2	97.7– 99.4
" 23	" " "	2.07	7.04	4.81	5.5	91.8	91.6	97.9– 99.4	98.1– 99.6
Oct. 5	24 Drive W.	1.65	5.56	5.5	6.19	93.6	94.6	97.5– 99.6[2]	97.8– 99.8
" 6	" " "	1.92	6.58	5.625	5.56[3]	94.8	93.2	97.2– 99.1	97.6– 99.0
" 8	" " "	1.98	6.66	5.125	4.75[4]	96.0	95.0	98.2– 99.1	98.3– 99.0
" 9	" " "	2.04	7.58	5.25	4.81	9 .1	95.2	97.4– 99.4	97.0– 99.2
" 14	Stope J. 20	3.32	11.0	3.81	3.69	90.3	91.5	97.7– 98.6	97.9– 98.4
" 15	" " "	3.11	10.7	4.31	3.5	89.6	89.8	98.4– 98.4	98.0– 98.7
" 16	" " "	3.44	11.0	3.88	3.69	90.3	90.8	98.0– 98.5	98.4– 98.7
" 20	19 Station	4.9	14.0	2.31[5]	2.44	90.5	89.6	98.0– 98.5	98.2– 98.7
" 21	" "	5.1	13.7	1.44	2.0	91.0	91.7	98.2– 98.3	98.0– 98.4
Nov. 1	Surface	4.6	21.0	5.19	4.5	93.2	95.2	——	——
" 2	"	4.0	20.0	3.31	3.81	92.5	95.0	97.8– 97.4	98.0– 98.8
" 3	"	4.12	17.6	3.125	4.125	92.8	95.0	97.5– 97.8	97.5– 98.2
" 4	"	4.22	18.5	3.19	4.19	92.7	94.7	97.4– 97.2	97.6– 98.6

[1] Skin temperatures were taken on the cheek about half-time. Mouth temperatures were taken before commencing and after stopping work, the first on the surface or foot of the shaft, the last in the working place after stopping work.

[2] Mouth temperature of observer A. G. (white man) rose to 99.3° F. after two and one-half hours. On the 28th, mouth temperature of observer A. G. rose to 99.7° F. after two and one-half hours, and he lost 1 pound and 8 ounces in weight in five hours.

[3] Native attendant lost 2.81 pounds.

[4] Native attendant lost 2.44 pounds.

[5] This includes urination.

form work at the rate of 4,500 foot-pounds per minute for a period of eight hours. This refers, of course, to a hardened white laborer in the open air at sea level. On one occasion at 19 Station, the rotary boy made an average of 4,600 foot-pounds per minute, but never repeated this output. It was unfortunate that during the surface tests in June, when the weather was cold, the rotary machine was very much underloaded, consequently the output was much below the boy's normal capacity. By the time the surface tests were being repeated, the weather had become warm and an opportunity of carrying out tests on the surface with a high cooling power did not again present itself.

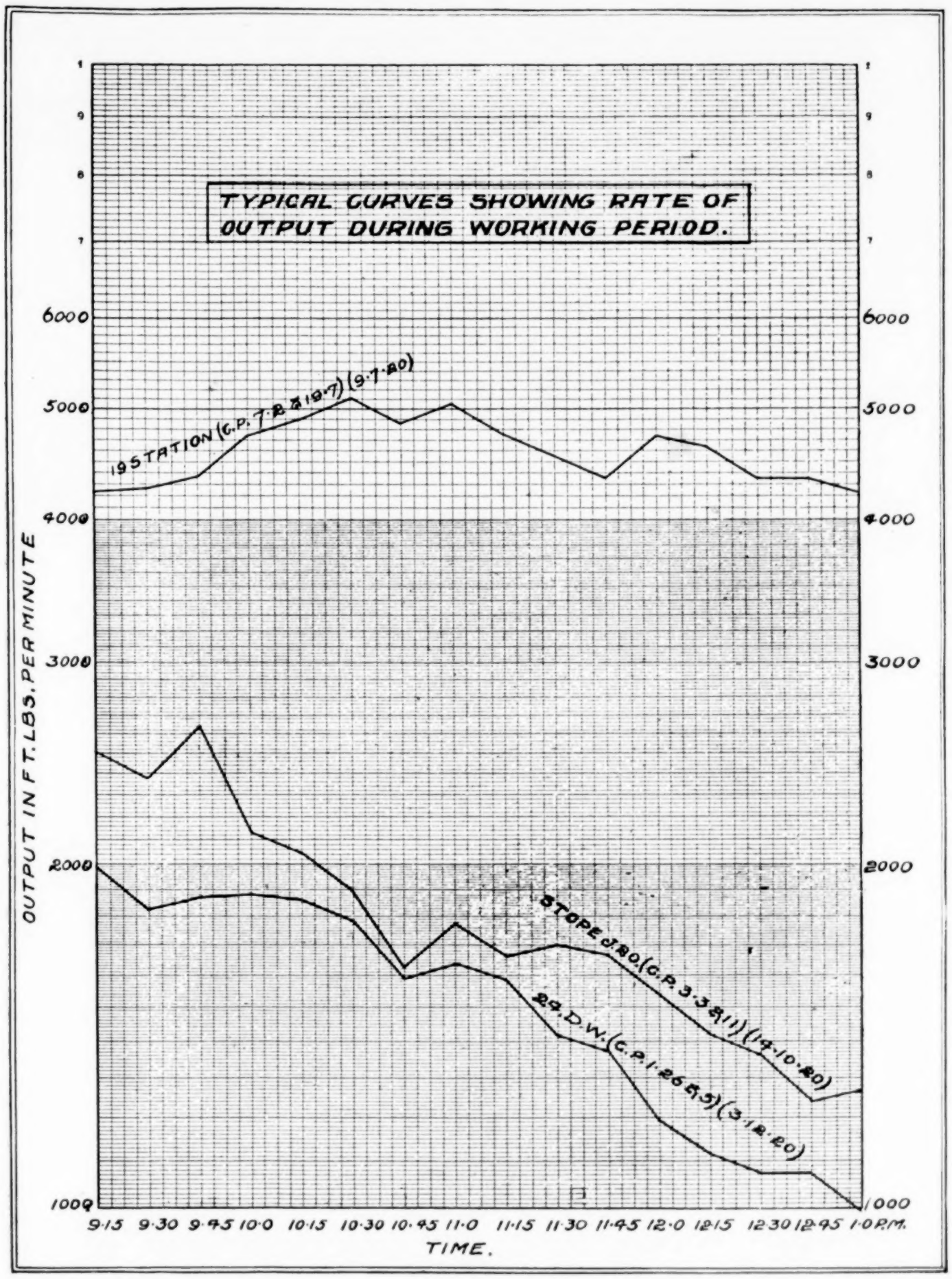

FIG. 12.—Typical curves showing rate of output during working period.

Attention is drawn to the variation of the output of the rotary machine with the atmospheric conditions. At

first, in 23 Drive East, the output was high, but after a few weeks in that place and 24 Drive West, the output fell considerably and the fatigue induced was very great. There was every sign that this was also true of the hammer machine. This was before the summer had set in. The correspondence between the rotary and hammer outputs may be judged by the fact that taking the last series of ordinary tests (November 1 to December 3) the ratio of outputs in the worst place and the best place was, in the case of the rotary machine, 0.637 to 1, and, of the hammer, 0.64 to 1.

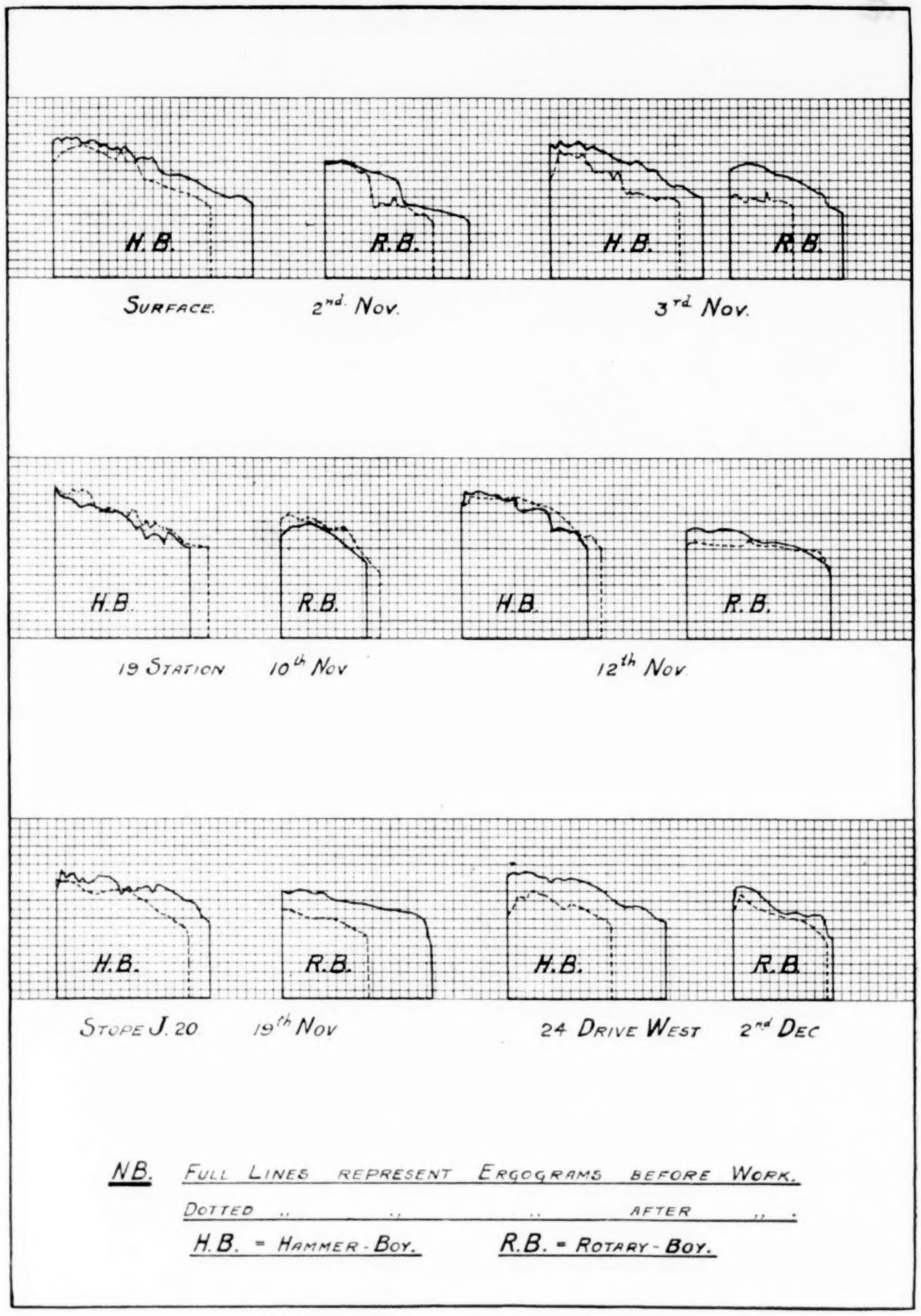

Fig. 13.—Typical finger ergograms.

In the next series of tests in 24 Drive

West (November 23 to December 3) the output of the rotary machine had risen considerably, although the cooling power had fallen from its previous average; moreover, the fatigue induced was not nearly so great. It has been suggested that this may be due to practice, though increase due to practice is not shown in the output in 19 Station, either in the series of November 9 to 12 or in the last series (December 21 to 23), both of these being much lower than in the first series in 19 Station (July 6 to 9).

We think a more rational explanation is that after the weather had been hot for a considerable period the basal metabolism of the natives was notably rereduced and consequently less heat produced. Benedict[1] has found, on tests carried out on an athlete, that the basal metabolism in winter was about 12½ per cent. greater than that in summer. Another way of looking at this question is to consider that in the cold weather, for about sixteen hours of the day, the man's organism is trying to maintain heat against the heavy heat loss, then is subjected for several hours to conditions in which he has difficulty in getting rid of heat; whereas, when the weather has been hot for some time, the organism is continuously trained in heat dissipation and has much less difficulty in dealing with hot conditions. Moreover, the blood becomes more viscous in cold weather than in hot, hence when it has to be pumped rapidly round the cutaneous blood vessels in an effort to get rid of heat, the work of the heart is increased.

The decrease in output in the best place underground, *viz.*, 19 Station, from the July series to the November series may be partly accounted for by decreased cooling power and partly by the fact that the vital energy of the natives had somewhat decreased. Just after return from holiday they both seemed in splendid form and experienced very little fatigue, even after performing large amounts of work. Thus, provided there was adequate cooling power to carry off the heat produced, there was no difficulty in performing large outputs of work.

In comparing the output on the surface with that at 19 Station, the effect of altitude, which is considerable, should be borne in mind.

The effect of a period of rest of twenty minutes at half-time can be estimated better by taking the ratio of the average amounts of work done after half-time in a series of tests to the total amount of work performed during the four hours, and comparing this ratio with the corresponding ratio for a similar series without rest, rather than by comparing the actual amounts done after time in the two series, as in the latter case the condition of the subjects may have varied. Comparing the series without rest in 24 Drive West (November 23 to December 3), the ratio of work done after half-time is 43 per cent. of the whole; in the corresponding series with rest, the ratio is 41.5 per cent., so that in this case the rest shows no advantage.

In the best underground place, 19 Station, the series with rest gives a ratio of 46.3 per cent., and without rest 43.3 per cent., showing a slight advantage due to rest. The outputs of individual days are, however, so variable both in total amount and in the distribution of work over the four-hour working period that the effect of rest is not sufficiently great to swamp these variable factors.

[1] Benedict, F. G.: Factors Affecting Basal Metabolism. Jour. Biol. Chem., 1915, *20*, 293.

In order to demonstrate clearly the effects of simply stirring up the air in oppressive conditions, a fan was taken down, erected and run on two days after the series of tests in 24 Drive West. The fan was a case fan, with an inlet 12½ inches in diameter, driven by a water motor of the Pelton wheel type, consuming about 6 gallons of water per minute, with a nozzle of 5/32 of an inch in diameter and 90 pounds pressure per square inch. It was erected at the end of the drive and placed so as to blow a current of air, first over the hammer boy, who was 10 feet away from it, and then over the rotary boy, who was 7 feet further on. The air volume is estimated at 2,000 cubic feet per minute.

On the first day, a rest period of twenty minutes was taken as in the preceding series, the "kata" readings being taken midway between the hammer and rotary boys. The output is compared with the average output of the preceding series and gives an increase of 46 per cent. On the second day, no rest was taken, two sets of "kata" readings were taken, one at each working boy, the hammer boy being nearer the fan getting more cooling power than the rotary boy. The output is compared with the average of the series without rest (November 23 to December 3), and gives an increase of 32 per cent. More weight, of course, should be attached to the first comparison, as the tests followed on and were not separated by an intervening series as in the second comparison.

To ascertain whether the fan draught had the effect of raising any dust, dust samples by sugar-tube were taken: (1) before the fan was started; (2) sometime after it had started. The results were: (1) 1.2 mg. per cubic meter; (2) 0.6 mg. per cubic meter; showing that, at any rate, there was no raising of dust by the fan. Both results are very low, and the difference is within the range of experimental error, so that it cannot be taken for granted that the fan produced a smaller dust content.

The figures giving loss of weight (Table 4) are interesting, and, though somewhat variable, show much greater loss in the hot places than in the cool. The loss on the surface is much greater than in 19 Station in spite of (or perhaps on account of) the higher wet cooling power, and is more on a par with the loss in Stope J.20, where the cooling powers, both wet and dry, are lower, the former much lower. The much greater moisture evaporation from the respiratory tract will partly account for this, though the evaporation from the moist skin is also much greater in a dry atmosphere.

There is great significance in the values of skin and mouth temperatures; the former gives a very good indication of the effort to get rid of heat by radiation and convection, and it will be observed that the values are higher in atmospheres of lower cooling power. The mouth temperatures were taken as an estimate of body temperatures. Although rectal temperature is a much better indication of body temperature, it was not considered advisable to adopt this method with natives. These readings clearly indicate that in the conditions of 23 Drive East and 24 Drive West, the organism was not successful in getting rid of heat with consequent rise of temperature to an excessive degree. Readings taken in the series November 23 to December 3 showed similar rises in mouth temperature, such as 99.6°, 99.9°, 100° and 100.2°F. When we came to Stope J.20 with cooling power about 3.3 and 11, the temperature was maintained more nearly normal. In 19 Station and on the sur-

face there was little indication of rise above normal temperature.

In Figure 14 an attempt is made to correlate output of work with cooling power, due to regard being paid to accidental and unusual factors. The hammer outputs in Stope J.20 have been more or less neglected, as these are

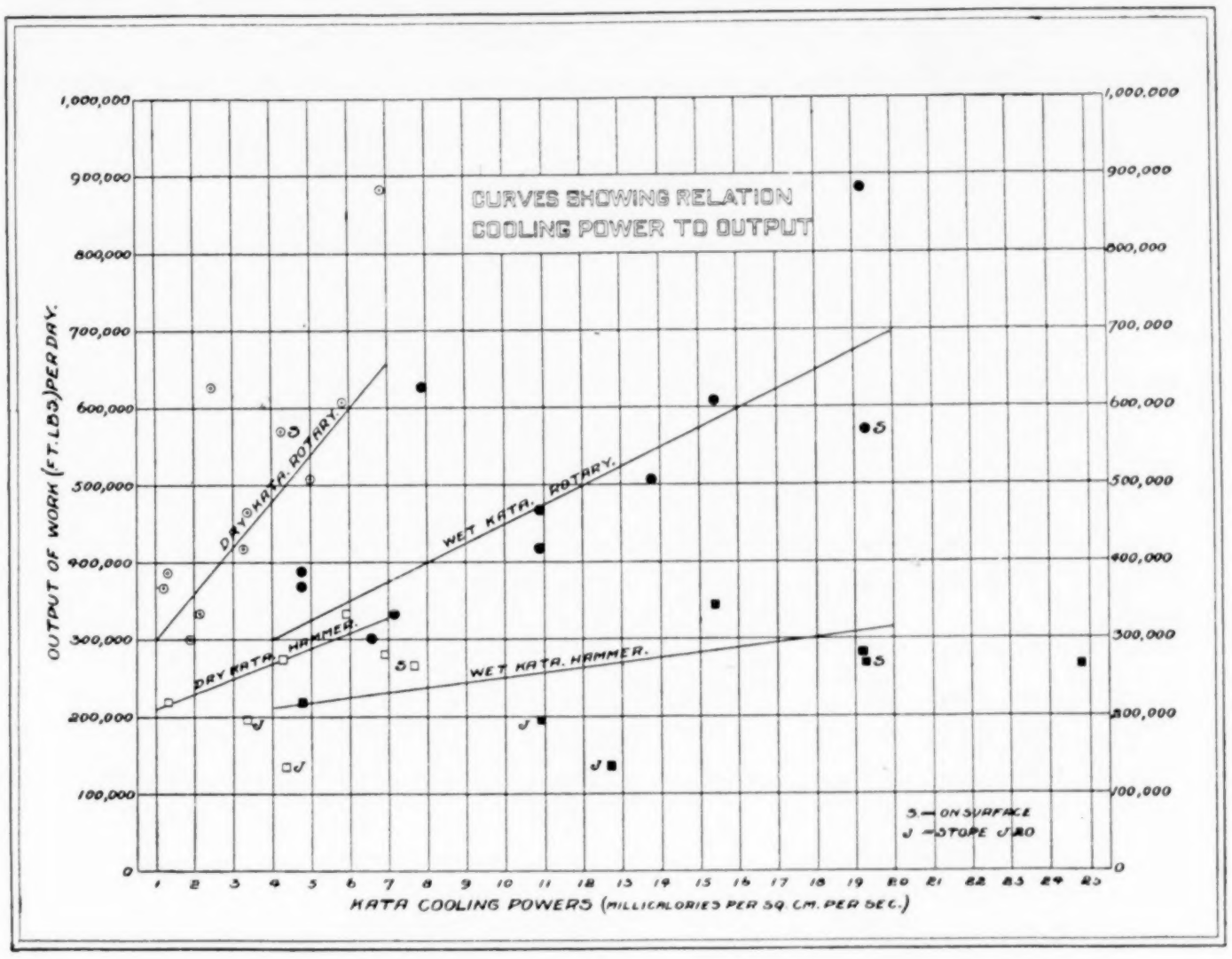

FIG. 14.—Curves showing relation of cooling power to output.

probably low, partly owing to the awkward posture of the hammer boy and partly, as was discovered later, owing to the fact that he was screened by a timber pillar from the slight air movement and had a lower cooling power than the readings give. Also the wet cooling power on the surface, though high, was not accompanied by higher output as the dry cooling power was low. The surface points are marked "S," and those for Stope J.20, "J."

As the outputs for the hammer for part of the series were not available, the rotary figures will be a much better criterion of the average for the whole test period. Neglecting the surface readings, there is a very close correspondence in the curves drawn between the wet and dry cooling power values, the corresponding wet and dry readings of underground conditions giving practically the same output of work; for instance, a dry cooling power of 4 gives 480,000 foot-pounds output, the corresponding wet cooling power is 11, which gives approximately the same output, so that in estimating working efficiency it does not matter whether we take the dry or wet cooling power curves. It is probable that the working efficiency will increase with cooling power up to 8 dry "kata," but, not to make the conditions too rigorous, we will assume that working efficiency is 100 per cent. at dry cooling power 6. We then get a relation between efficiency and dry cooling power as follows:

Dry cooling power	1	2	3	4	5	6
Working efficiency per cent.	50	60	70	80	90	100

The curve giving the relation between cooling power and output will rise more rapidly at the low cooling powers and less rapidly as it approaches 8 dry cooling power, making a curve convex upwards. But it simplifies computation to assume that it is a straight line, and the average error in efficiency over a range of various cooling powers is small and is probably fully compensated for by lowering the standard of cooling power for 100 per cent. efficiency.

In order to form an estimate of the general loss of output incurred in a mine due to inadequate cooling power, a representative section of a mine was chosen and "kata" readings and wet and dry bulb temperatures were taken in sixty-three different positions, thirty-six of which were positions where men were working. The cooling powers, estimated working efficiency, number of men, equivalent number at full efficiency, are tabulated in Table 5, and the overall efficiency is arrived at by dividing the sum of equivalents by the sum of actual men working, thus:

$$\text{Efficiency} = \frac{215.5}{272} = 0.79, \text{ or } 79 \text{ per cent.}$$

TABLE 5.—COOLING POWER AND ESTIMATED WORKING EFFICIENCY IN DIFFERENT MINING POSITIONS

No.	Place	Cooling Power		Working Efficiency	No. of Natives	Equivalent at Full Efficiency
		Wet	Dry			
				%		
1	Incline	23.8	9.24	100.0	1	1.0
2	"	30.8	11.25	100.0	1	1.0
3	Drive	8.3	2.65	66.5	5	3.32
4	Stope	10.5	3.62	76.2	21	16.0
5	"	11.4	3.65	76.5	17	13.0
6	Drive	15.3	4.75	87.5	6	5.25
7	"	21.8	7.4	100.0	3	3.0
8	Incline	15.4	5.9	99.0	1	0.99
9	Drive	8.6	2.34	63.4	3	1.9
10	Stope	16.4	4.98	89.8	22	19.75
11	Drive	10.25	3.4	74.0	6	4.44
12	Incline	21.0	8.1	100.0	1	1.0
13	Drive	10.5	3.43	74.3	9	6.68
14	Stope	10.9	5.12	91.2	10	9.12
15	Drive	14.5	4.84	88.4	25	22.1
16	Station	16.4	6.32	100.0	1	1.0
17	Drive	7.5	2.0	60.0	3	1.8
18	Stope	11.1	3.9	79.0	15	11.85
19	Station	35.0	12.3	100.0	11	11.0
20	Drive	18.0	6.82	100.0	2	2.0
21	Stope	13.8	4.11	81.1	9	7.3
22	Drive	6.72	2.46	64.6	2	1.29
23	Incline	30.8	11.5	100.0	1	1.0
24	Winze	9.3	2.6	66.0	5	3.3
25	Winze	5.4	1.48	54.0	6	3.29
26	Incline	26.2	9.42	100.0	2	2.0
27	Raise	3.22	0.975	50.0	4	2.0
28	Incline	17.4	7.1	100.0	1	1.0
29	Drive	7.5	2.1	61.0	8	4.88
30	Incline	18.0	6.8	100.0	1	1.0
31	Drive	12.9	3.24	72.4	10	7.24
32	Drive	12.7	3.2	72.0	6	4.32
33	Incline Bottom	7.1	2.17	61.7	40	24.68
34	Drive	9.0	2.93	69.3	5	3.46
35	Crosscut	10.5	3.8	78.0	10	7.8
36	Crosscut	8.7	1.27	52.7	9	4.75
	Total				272	215.51

It is thus estimated that 21 per cent. of output is lost through inadequate cooling power. It is not implied that all this loss is avoidable loss, as it may be impossible to bring up the cooling power to the arbitrary standard, but it shows, at any rate, how important it is that adequate cooling power be maintained if at all possible. Moreover, this loss is loss of output only and does not include the losses due to the increased morbidity which must surely follow on the excessive strain and fatigue associated with work in oppressive atmospheres; such losses would be hospital charges and cost of replacing sick men.

It must be borne in mind, moreover, that the above estimate is based on tests where the native was under continual supervision and observation, where the frequent periodical reading of his output, or attention to his machine by the observer, was a constant spur to keep him working up to his capacity. In the absence of such supervision it is very doubtful whether he will keep up his best effort when fatigued. When work is going on in hot places, like "winzes" and "raises," it is observed that the white miner goes into the working place as little as possible, preferring to stay in the cooler level, with the consequence that there is every tendency to give the natives inadequate supervision.

In connection with the cooling powers taken in the representative section referred to, some were very low; in one instance dry cooling was 0.975, and wet, 3.22, while in other places the wet cooling power was 40. In many instances the working places are extremely hot and the waiting places extremely cold, the observer frequently remarking that in returning from a hot place he was severely chilled. Such extremes of cooling power cannot but have a very prejudicial effect on health and expose a man to grave danger of severe chill, not only of the respiratory membrane, thus lowering resistance to bacterial invasion and infection, but also of the general organism, thus tending to produce congestion in, let us say, the kidneys or the liver. Such dangers may have a considerable influence on the incidence of pneumonia.

It has been recognized for a considerable time that hot humid atmospheres tend to lower the resistance to tuberculosis. Pulmonary tuberculosis is more prevalent among classes of people who work in such atmospheres, and the introduction of cooler conditions underground should do much to diminish the incidence of respiratory disease and tuberculosis among the mine workers.

There has grown up recently a considerable body of informed medical and other technical opinion that even silicosis is not due to dust alone, but that the damage to the lungs is contributed to by hot, oppressive atmospheric conditions and, perhaps, by some other factors. D. Harrington of the United States Bureau of Mines, after four or five years of careful observation, seems also to have come to this conclusion. In a paper read before the Lake Superior Prevention of Accidents Conference on July 23, 1920, he says:

> By far the most dangerous condition is that of breathing dusty air in a hot, humid, stagnant place all day and then going home in perspiration-saturated clothing through air frequently many degrees below zero. . . . . The effectiveness of good ventilation in preventing miners' consumption is illustrated by two mining districts in the United States. In both districts the mines have cool rock and air, dry siliceous ore, easily broken into fine dust, and the miners work hard. In one district the method of mining requires constant shooting, so the mines all have moving current of air at nearly all the working places; in the other, little or no air is circulating at working places. In the former, miners' con-

sumption is *practically unknown,* in the latter it is a *common disease* (italics ours).

Enough has been said to show the great importance of efficient ventilation at working places. The objection to the usual ventilation systems in many of the mines on the Rand is *that they fail where they are most required,* viz., *at the working places.* One reason for this is the inherent difficulty of getting an adequate flow of air from a central ventilating system through stopes, in winzes, raises and the blind ends of development drives. The cross-sectional area of the workings is very great compared with that of the shaft and drives, and a current to give adequate cooling power would require an enormous air volume to be drawn into the mine. Another reason is that *the great importance of proper ventilation is probably not thoroughly appreciated, and its bearing on efficiency is also, perhaps, not altogether common knowledge.*

It is beyond the scope of this report to go into the details of methods of ventilation which are likely to give satisfactory results, and in any case, it is probably beyond the capability of any one man to map out a complete scheme, satisfactory from the point of view of good distribution, of cooling power, dilution of poisonous gases and dust content and at the same time compatible with low first cost, low maintenance charges and convenience. Experiments with various methods would have to be made, and experience gained—practical ideas would suggest themselves as progress was made. It will not, however, be out of place to suggest some of the lines along which experiment might fruitfully be made. Good general distribution may be helped very considerably by a proper system of doors and regulators; but the best results will, no doubt, be obtained by a system of small auxiliary fans placed at strategic points, augmenting the current in the hottest places. This is done very effectively in one mine on the Rand where there is an extensive system of auxiliary fans distributing the air and blowing it into the workings, particularly the ends of development drives. In this connection, it is interesting to note that, according to the statement of the manager, the dust content in the workings is only about one-third of the general average on the Rand, and the carbon dioxide content is 0.17 per cent.

In order to get adequate cooling power in the stopes, the air current from the main circulation, or even from auxiliary branch circulations, may not be adequate, and strictly local circulation may have to be adopted. From the point of view of power cost this would, no doubt, be most economically carried out, where electric power is accessible, by portable electric fans supplied through flexible cables connected to plugs in the levels, with flexibles suspended, let us say, from hooks screwed into small fiber plugs in the hanging, the fans and flexible cables to be removed before blasting. As water at high pressure is available at the workings, another method which might be considered is to have propellor fans driven by water motors—the latter would probably have a water consumption of from 1 to 2 gallons per minute. A third suggestion which would be quite effective would be to have hand-driven portable fans, or, perhaps in suitable places, some adaptation of the "punkah." The loss of mining work of the natives driving these appliances would be much more than made up by the increased efficiency of the other workers.

The ventilation of raises, winzes and blind ends of drives has always been a

difficult problem. We suggest that a continuous circulation of air in such places should be carried on during working hours, either by power or hand-driven fans or by ejectors—whichever is the most economical—with the aid of canvas piping. By these means the temperature in the working places should be lowered to approximately that of the general circulation, and the cooling power increased to an adequate figure by the local current of air produced.

Summary of Conclusions

1. When the cooling power of the atmosphere is below 6 units by dry "kata" and, let us say, 16 by wet "kata," the working efficiency of a native (stripped to the waist) falls off. In bad places, where the cooling power is only 1.5 units (dry) and 5 (wet) or under, the average efficiency is only about 55 per cent., the body temperature rises to an undesirable degree and extreme fatigue may be produced by work.

2. Working in hot places is a greater physical strain on the worker in winter than in summer.

3. It is not advisable to put a native just back from holiday, or a new recruit, in a bad place. He will probably do better in the hot place after some training in good or moderately good places.

4. The effect of a short rest at half-time is not sufficiently pronounced to make it worth while.

5. General "kata" readings in several mines show that workers, under present conditions, may be subjected to extremes of cooling power which may severely overtax their defensive mechanism.

6. A small fan, with a capacity of about 2,000 cubic feet of air per minute, operated about 10 to 20 feet from the worker, may increase the output (under experimental conditions) by as much as 46 per cent.

7. If an average native works continuously underground at full capacity for four hours, without an unduly prolonged rest period, it is apparently all that he can do efficiently under the worst atmospheric conditions obtaining during the experiment. This time would probably be somewhat longer in those places where the conditions approximate those found in 19 Station during the winter—*i.e.*, a dry "kata" of 7 units and a wet "kata" of 19 units.

BOOK REVIEWS

Pneumonia. By *Frederick Taylor Lord*, A.B., M.D., Visiting Physician, Massachusetts General Hospital. Cloth. Pp. 69, with title pages. Cambridge and New York: Harvard University Press, 1922.

This small book is a reliable statement of the hygienic and medical position of pneumonia at the present time. It consists of the material presented at one of the Harvard Health Talks given to lay audiences during the past winter, and consequently can be utilized as a model for the presentation of the educational material to non-medical groups. Industrial physicians and nurses desiring guidance in the development of educational campaigns against respiratory infections will do well to avail themselves of Dr. Lord's text.—*Cecil K. Drinker.*

DEFINITION OF THE PHYSICIAN IN INDUSTRY.

At a recent meeting of the Conference Board of Physicians in Industry, the following definition of the *Physician in Industry* was adopted:

> The physician in industry is one who applies the principles of modern medicine and surgery to the industrial worker, sick or well, supplementing the remedial agencies of medicine by the sound application of hygiene, sanitation and accident prevention; and who, in addition, has an adequate and co-operative appreciation of the social, economic, and administrative problems and responsibilities of industry in its relation to society.

The discussion leading up to the formulation of this definition extended over several months. The question was viewed from all angles and many suggestions were considered for including in the definition an outline of what his duties and functions were.

It was felt, however, that in order to avoid a complicated statement it would be better to include in a definition only the broad fundamental principles upon which the work of the physician in industry is based, leaving to subsequent elaboration the finer details. It was pointed out that the definition adopted should emphasize both the medical attainments and the industrial requirements of the physician engaged in this work in order to make his duties clear both to the medical profession and to industrial management.

It is assumed that the physician engaged in industrial work is well grounded in the fundamentals of medicine and surgery. He is, first of all, a physician. It is obvious, however, that this alone, while equipping him for satisfactory service in private practice, does not meet fully the requirements of industrial work. In his industrial experience he has, of necessity, to deal with questions of sanitation, hygiene, and accident prevention as applied to large numbers of people working in comparatively close association. Only by special knowledge of the work in hand will the physician be able satisfactorily to discharge his duties. His knowledge of plant processes, together with the physical examination of applicants for employment and of workers already engaged, will enable him by judicious placement to reduce materially the accident and morbidity hazard and rate.

It must be realized that many of the qualifications for successful medical work in industry are of a non-medical nature, and call for a knowledge of the laws of social and industrial economics and of the administrative problems which arise in the conduct of an industrial medical department. The physician in industry must have a clear conception of the responsibilities of the industry to its workers and through them collectively to the community. On the other hand, he should recognize clearly the duties of workers to the industry in which they are engaged. It is an intelligent appreciation and consideration of these problems that make for the success of the work of the physician in industry.

It is hoped that this definition will tend to remove misconceptions as to the work of the physician in industry, and establish his position and his work upon a basis satisfactory alike to the physician and to the industrial organization.